THE INFLUENCE OF TEMPERATURE ON THE RATE OF LOCOMOTION IN AMOEBA

A Dissertation

submitted to the Board of University Studies of the Johns Hopkins University, in conformity with a requirement for the Degree of Doctor of Philosophy,

by

Alphonse M. Schwitalla, S.J.

1921.

Baltimore, Maryland.

175,588

ACKNOWLEDGMENT.

The ready interchange of views made possible by the fact that so many of Professor Mast's students are investigating problems connected with amoeboid motion, makes the writer feel that he is indebted to every investigator in the zoological laboratory in this University.

He wishes, however, to acknowledge in a special way, his obligation to Professor S.O. Mast, at whose suggestion and with whose constant assistance this investigation was carried on. Professor Mast's knowledge and experimental skill are ever at the disposal of his pupils. For this he may be thanked, if ever so inadequately. The ideals of scientific research, however, which Professor Mast instils into his pupils, are for them an acquisition that defies gratitude.

The writer wishes, moreover, to acknowledge gratefully the assistance generously rendered him, by

Professor H.S. Jennings,

Professor Burton E. Livingston,

Associate Professor R.P. Cowles,

Associate Professor Walter A. Patrick,

The Reverend Joseph Kelley, S.J.,

Professor of Physics, Loyola College, Baltimore,

Sister Catherine Rogers,

of the Sisters of Bon Secours, Baltimore,

Mr. Samuel Geiser, A.M.

ANALYSIS.

INTRODUCTION.

The present investigation was undertaken with the purpose of determining the quantitative relation of temperature to the rate of locomotion in Amoeba. In agreement with the results of other investigators, who have studied the influence of temperature upon the life processes of the protozoa, it was found that there was a very close correlation between temperature and the rate of locomotion. The statement occurs frequently in the literature bearing upon this point, that the rate of locomotion of other protozoa, as well as of Amoeba, increases with rising temperature. Davenport ('08) cites Rossbach ('72) and Schürmayer ('90) as having established different rates of locomotion of the ciliates, for different intervals on the temperature scale. They seem to have pointed out rather definitely that between 25 and 30 degrees, locomotion reaches an optimum for both rate and accurate coordination; that between 30 and 35, the high rate may be maintained but movement becomes very irregular; that, finally, near 40 degrees, progressive movements become slower and gradually cease. While these findings are definite enough in their delimitations of temperature conditions for locomotion of ciliates, evidently the reactions of the organisms are reported merely in descriptive and not in quantitative terms. For Amoeba, Rhumbler ('98) implies rather than states definitely the dependence of the rate of locomotion upon temperature. Similarly, Karl Gruber ('12, p. 326) found that cooling retards the rate of locomotion of A. proteus, while an increase in temperature to 35 degrees increases the rate. He states, however, that even at 30 degrees, this increase in rate is only temporary, and that a resting period ensues within a very short time. Schaeffer ('20) says of Amoeba: "In general, the lower the temperature the slower the movement. This has been frequently observed and recorded." Very little, therefore, seems known concerning the exact quantitative

measurement of the degree of dependence of locomotion and allied physiological processes on temperature in the protozoa, and specifically, in Amoeba.

Regarding the absolute rates of locomotion in Amoeba, the data seem very meagre. The subject is treated for the most part in casual notes. Rhumbler ('98, pg. 123) teels us that A. verrucosa may move at a rate of 0.5 per second, at a rate, therefore, of 30 per minute. A. striata, according to the same author, moves at a rate of 60 per minute, as does also A. limax. Schaeffer ('20, pg. 123) estimates the rate of movement of A. proteus as 600 per minute, and in the present investigation the average rate of all the amoebae studied at various temperatures, was found to be 625 , a result which is in very close agreement with Schaeffer's measurements. In discussing his results, Rhumbler (l. c., pg. 123) touches upon a feature of locomotor behavior, which will have to be stressed in the following pages, the variability of the rate of locomotion even at constant temperatures. One of his specimens of A. geminata, Pen. changed its rate of locomotion from 90 to 150 during five minutes, and he describes the occurrence of occasional rates of locomotion, so rapid that they could not be estimated even approximately by the methods of measurement which he employed. It seems likely, as we shall see, that these variations in rate are manifestations of a locomotor rhythm.

Before going on, it is necessary to define "locomotion" more accurately. Amoeba may pass from place to place in a variety of ways.

a) It may be passively transported in a current of water. Obviously, the rate of this transportation is no indication of physiological activity, and hence, for our present purposes, such passive transportation has little significance.

b) Amoeba may be passively transported, and at the same time the protoplasm may be flowing. Gruber has spoken of this as "active-passive" transportation. If in this form of locomotion we could definitely measure the rate of protoplasmic flow, the data would probably be of value in the present problem. Obviously, however, for such a mode of locomotion, the rate of protoplasmic flow would be difficult to ascertain with any degree of assurance.

c) Amoeba may transport itself actively by "crawling", that is, by protoplasmic flow. Sometimes, when it is progressing in this way, Amoeba is partially detached from the substratum, and uses its pseudopods as braces for further progress. At other times, it is entirely, or at least at its two extremities, attached to the substratum. It is this latter form of locomotion which unmistakably expresses the physiological activity of the animal. It is this form of locomotion, therefore, which was investigated, and its dependence upon temperature was ascertained.

During the last twenty years or more, it has become customary to express the dependence of a physiological process upon temperature in terms of a temperature coefficient. We shall come back to a discussion of the history of this subject and of the possible meaning of the temperature coefficient in Part III of this paper. For the present, it may suffice to call attention to the fact that but few investigations have been undertaken thus far with the special purpose of determining the temperature coefficient of physiological processes in the protozoa. Kanitz ('07) has calculated the temperature coefficients from the data of Rossbach ('72), and for observations of his own, on the rate of contraction of the vacuoles in several ciliates. Barian, cited by Winterstein (cf. Kanitz, '15), calculated the temperature coefficient for the rate of contraction of the vacuole in Vorticella, the data being taken from a paper of Ostermann's

('04). Khainsky ('10) studied the same physiological process from this same viewpoint in Paramecium. The temperature coefficient of the rate of reproduction of the protozoa, has also been studied in some forms. Blackman ('08) did this for Chilomonas from data in a paper of Maltaux and Massart ('06); Woodruff and Baitsell ('11) for Paramecium; Borowsky ('10) for Actinosphaerium. A third physiological phenomenon, the nucleo-cytoplasm relation in its dependence on temperature has been studied by Jollos ('13) and by Hautmann ('09), but their data, while extremely valuable and interesting, are not easily expressible in terms of a temperature coefficient. Thus far, a search of the literature has not disclosed any investigation of the temperature coefficient of a locomotor process among the protozoa.

Our purpose in this investigation, then, is to study the influence of temperature upon the rate of locomotion in Amoeba, understanding locomotion to mean active locomotion by protoplasmic flow.

MATERIAL and METHODS

A. Material.

B. Methods.

A. MATERIAL

The amoebae used in this investigation were cultured from a supply found in a stream of spring water which is exposed to contamination from sewage and surface water. This stream is located near the biological laboratory of the Johns Hopkins University and is known as Stony Run. The amoebae were cultured in ordinary finger bowls. Considerable effort was made to keep the various cultures of uniform density in relation both to the number of individuals in any one culture and to the amount of food material present. Equal volumes of water from the same stream in which the amoebae had been found were supplied to the various cultures, and approximately equal quantities of boiled timothy hay, cut into short lengths of about 2 cms., were added to the culture dishes at intervals of about two weeks. It was realized, of course, that despite even such care, the cultures would become decidedly unequal in density with the lapse of time, but they were kept fairly uniform in appearance, at least, during the progress of the work. Abundant food was kept in the culture so as to insure favorable and equal nutritional conditions, and to exclude, as far as possible, the influence of food-seeking as a factor in determining the rate of locomotion.

Most of the individuals in the various cultures conformed to the diagnosis of Schaeffer's ('16) new species A. discoides. They varied in length, during locomotion, from about 300 to 400 . They were pale bluish by transmitted light. Their pseudopods enlarged with a single well-coordinated stream of endoplasm and no ridges were observed on the ectoplasm. The nuclei of these individuals were discoid with rounded edges and smooth surfaces.

In every culture, however, some of the amoebae conformed more nearly to Schaeffer's description of A. proteus. They moved forward with [illegible]

pseudopods, which enlarged with several adjacent streams of endoplasm. They were rather yellowish by transmitted light and their nuclei were variable in shape. -- No effort was made in the course of the investigation to keep these two classes of amoebae apart, and, though it is quite certain that most of the observations were made upon A. discoides, some were made upon A. proteus. Schaeffer's new diagnosis of the species of amoebae was not available until the present investigation had been completed, and the importance of the diagnostic characters was not appreciated while the work was in progress. It is probable, therefore, that the amoebae used in the present investigation belonged to two different species, and it is quite impossible at present to separate the experimental data for each species with any degree of assurance.

In selecting individuals for experimentation, some little effort was made to procure individuals of about the same size. In the beginning of the work, the amoebae were actually measured, but later on the experience gained was deemed sufficient to ensure fair constancy in the size of the individuals selected. Another factor that determined the selection of a given individual for study was its apparent activity. While those were chosen that seemed rather active, no long search was made to procure the most active individuals in a given culture. It was felt that by such random selection, individual differences would be most readily effaced in the averages. It will be clear to anyone who has worked with such material, however, that no guarantee of even approximate uniformity in the individuals studied can be given.

More than a hundred individuals were studied in this investigation. Those, however, which were used in the preliminary work, as well as those which showed no appreciable sign of locomotion after they had been observed for 15 or 20 minutes, are excluded from this report. Sixty-two

individuals were studied carefully and the results to be presented in the following pages are based upon the performance records of them.

B. METHODS

In its barest outline, the investigation was conducted by measuring the rate of locomotion of amoebae under known conditions of temperature. It was necessary, therefore,

1. To secure a definite temperature in the immediate environment of the amoebae and to vary this temperature.

2. To measure temperature accurately.

3. To measure time.

4. To measure the distance traversed in a given time interval.

5. To record the results.

6. To represent graphically the variations in the rate of locomotion.

7. To exclude, as far as possible, all factors, except temperature, which might affect the rate of locomotion.

1. Method for Securing a Definite Temperature and for Varying Temperature

Water of known temperature circulating within the chamber of a Pfeiffer warming stage was used for controlling temperature conditions. The Pfeiffer stage is essentially a closed, rectangular glass chamber (Fig. 1) with openings for the inflow and outflow of water and for inserting a thermometer. The external dimensions of the one used in this investigation were 9.2 by 7 by 1 cms. It was, therefore, sufficiently large to enable the observer to place it securely upon the stage of the microscope.

As ordinarily used, the animal to be studied is placed upon the upper surface of the Pfeiffer stage. Thus, the animal is supposed to be subjected to the temperature of the water circulating within the chamber. In the preliminary work on the problem, it was soon found, however, that considerable time, as much as four or five minutes, had to elapse before

Fig. 1.
Pfeiffer Warm Stage.

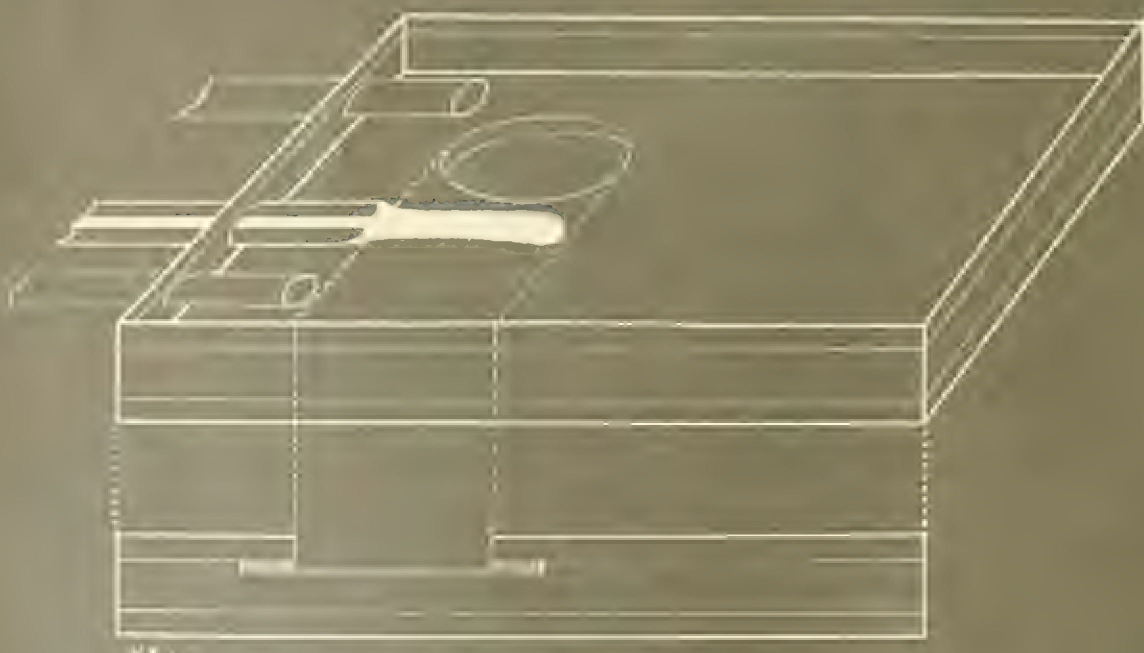


Fig. 2.
Pfeiffer Warm Stage.
(Modified)

the upper surface of the warming stage became even approximately isothermic with the interior of the chamber. This surface was exposed to the temperature of the room and the circulation of air. Consequently, its temperature showed rather frequent and wide fluctuations. Moreover, as the walls of the Pfeiffer stage are plate glass, 3 mm. in thickness, it took this mass of glass a considerable time to assume the temperature of the water circulating within. When temperature changes were to be made, therefore, the surface upon which the amoeba had been placed showed a very considerable lag.

To obviate these difficulties, the Pfeiffer stage was modified in a very simple manner. A circular opening, 2 cms. in diameter, was cut through the upper glass plate of the chamber. This opening was then closed by a glass disc, 0.28 mm. in thickness and 3 cm. in diameter, which was cemented to the inner, i.e. the lower surface of the plate with De Khotinsky's cement (Fig. 2). A cell was thus formed -- hereafter to be spoken of as a "depression cell" -- into which the amoebae were placed in their own culture medium. A cover glass was then placed over the animals. As the cover glass was 1.9 mm. in diameter, there was enough clearance between the edge of the cover-glass and the walls of the depression cell to permit a free interchange of gases between the atmosphere and the culture medium. Only a thin sheet of glass, .28 mm. in thickness, now separated the culture medium in which the amoeba had been placed from the water circulating within the chamber of the Pfeiffer stage. The lag of the temperature of the depression cell as compared with that of the chamber was thus greatly reduced.

Water was delivered to the warming stage through glass and rubber tubing from a series of six 19 liter reservoirs, which were kept on a shelf

50 cm. above the microscope stage. With its delivery tube entirely open, each reservoir could be emptied in about 25 minutes, giving a flow of .63 liter per minute. This rate of flow was found to be sufficiently fast to offset the influence of room temperature or other influences, which could cause fluctuations in the temperature of the depression cell. The delivery tubes from the reservoirs were connected with the intake tube of the Pfeiffer stage through glass Y tubes, and any one of the reservoirs could thus be tapped at will.

Before the beginning of a series of observations, the water in the reservoirs was brought approximately to the temperature at which it was desired to work. Just before the water was used, its temperature was again determined, and, if necessary, was definitely adjusted by the addition of hot water of broken ice, and then thoroughly stirred. The bulk of the water in each reservoir was found to be large enough to enable it to retain a given temperature for a considerable time.

To make a temperature change in the Pfeiffer cell, therefore, it was necessary only to close the clamp of the delivery tube from one reservoir and to open that from another.

2. Measurement of Temperature

Even after the modification of the Pfeiffer stage, just described, it soon became apparent that it was necessary to measure the temperature, not only of the circulating water, but also of the culture medium in the depression cell.

For determining the temperature of the water circulating in the chamber of the stage, a thermometer, graduated in two degree intervals and checked against a standardized thermometer, was used. The reading of this

thermometer was further checked not only by the water in the reservoirs, but also by that of the outflowing water.

The determination of the temperature of the culture medium in the depression cell proved to be somewhat more difficult. To measure this temperature directly, e.g. by inserting a thermometer into the culture medium, was not feasible. Since it was sufficient, however, to know the difference of temperature between the water circulating in the chamber and that in the depression cell, the temperature of the latter could be determined indirectly. For such indirect determinations, the use of thermo-couples is eminently adapted, and hence the electro-thermometer as described by Hill ('13) and Rogers and Lewes ('14) was modified to suit the requirements of the present investigation. This method, it will be recalled, depends on the principle that an electro-motive force is set up when the junction of two metals is subjected to a change of temperature.

Two such junctions formed into a circuit constitute a couple. If the two junctions are subjected to different temperatures, the difference of potential at one junction will be greater than that of the other, but the aggregate difference of potential in the circuit is proportional to the difference of the temperature of the two junctions. If a galvanometer is inserted in the circuit, the strength of the electro-motive force may be measured and the galvanometer scale-readings may readily be calibrated as degree-differences in temperature. From this it is clear that, if it is desired to measure the difference of temperature between two junctions, or the difference in temperature between two media in which they are immersed, the temperature of one of the media must be known.

The conditions in the present problem were such as to make the application of this principle very simple. As was said in the previous

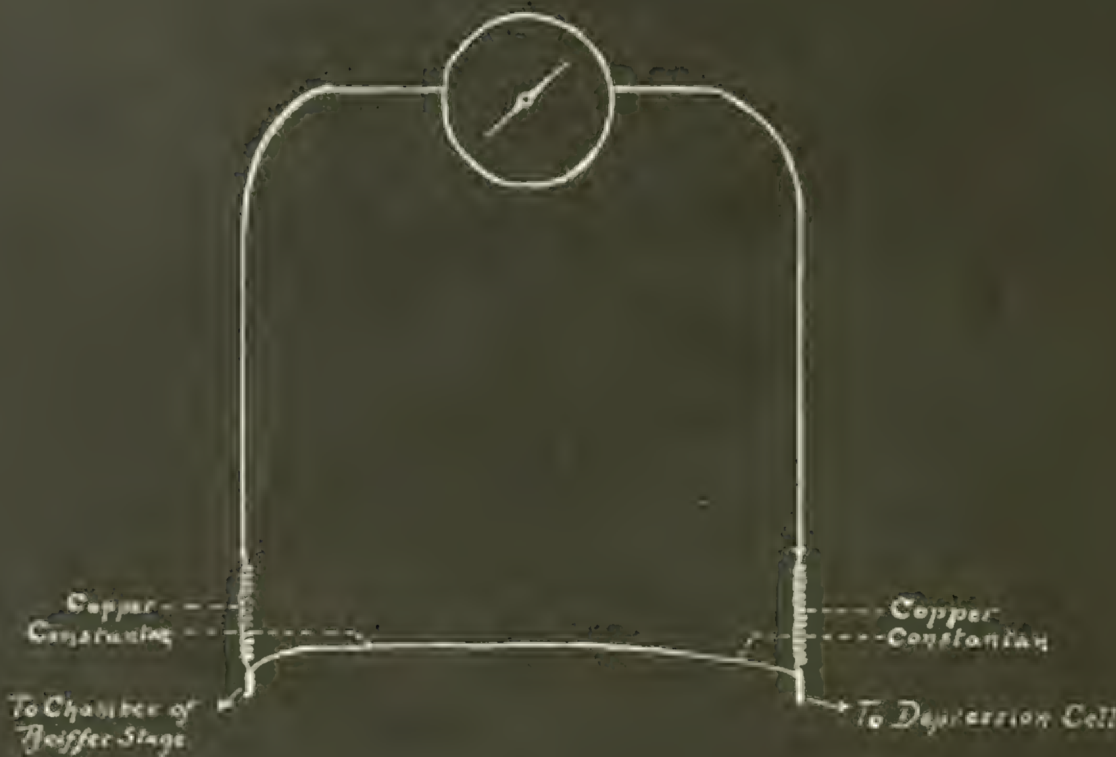


Fig. 3.

Connections for Thermo-
couple.

paragraph, the temperature of the water circulating in the chamber of the Pfeiffer stage was definitely known and could be easily checked. If one junction of a thermo-couple were inserted into this water and the other into the medium in the depression cell, the desired information regarding the temperature of the medium in the depression cell could readily be ascertained from galvanometer readings. The arrangement is diagrammatically represented in Fig. 3.

The couple was formed by No. 41 constantan and No. 40 copper wire. The constantan wire was 50 cm. long and this was soldered at either end to pieces of the copper wire, each 25 cm. long. The free ends of the copper wire were then soldered to leads of No. 28 copper wire, and these were connected with a galvanometer. As these junctions had to be immersed in water, they were covered with a thin coating of paraffin. One of the junctions was attached by means of rubber tubing to the bulb of the thermometer and inserted into the chamber of the Pfeiffer stage; the other was inserted under the cover glass in the depression cell.

The galvanometer used in this investigation was a D'Arsonval instrument, (Leeds and Northrup, Type P), mounted on an adjustable wall-board. Its resistance was 114 ohms, its sensitivity 100 megohms and its period about 8 seconds. The scale was supported on the usual scale arm at 50 cm. distance from the mirror of the galvanometer. A straight scale was used as it was intended to make readings at short distances only from the zero point. (See Fig. 6 for assembled apparatus).

The system was such as to give a deflection on the scale of the galvanometer of 9.7 mm. per difference of one degree. This value was determined as follows. The junctions of the couple were inserted into beakers containing water of different known temperatures, and the deflection

on the galvanometer scale was noted. From these data, the deflection per degree of difference were then calculated. To illustrate, a series of such determinations is given in Table I (a). The junctions are designated as 1 and 2 respectively and their temperature, which was the same as that of the water in which they were immersed, was determined by means of standard thermometers. These temperatures are entered in the first and second columns. In the third column are given the differences in temperature between the two junctions, in the fourth the observed deflection on the galvanometer scale, and in the last column the calculated deflection per degree. In this particular set of observations, the temperature of junction 1 was kept constant. The average of the five determinations, ranging in differences of temperature of the two junctions from 6.8 to 15.7 degrees, gave a deflection of 9.7 mm.

The test, however, does not meet accurately the conditions that were encountered in using the Pfeiffer stage. In the present problem, it was necessary repeatedly to change the temperatures of both junctions. To study the action of the electro-thermometer under such conditions, the temperature of the water of both beakers in which the thermo-junctions were inserted, was changed. Table I (b) contains the records for such a series of observations. The temperature of junction 1 varied from 30.2 to 9.0 degrees; that of junction 2 from 30.6 to 28.8 degrees.

It will be seen from this table that in this series of observations the difference of temperature ranged from .5 to 19.1 degrees, while the average deflection for a difference of temperature of one degree varied from 12.5 to 9.5 mm. The average of the various readings gave a deflection of 9.9 mm. for a difference of one degree.

When the difference of temperature between the two junctions was very small, the same constancy of value of the deflection for a difference

T A B L E 1

Galvanometer Deflection per Difference of One Degree Temperature between Two Junctions of the Thermo-Couple

a) With Variation in Temperature of One Junction.

Temperature of Junction 1 Degrees	Temperature of Junction 2 Degrees	Difference in Temperature Degrees	Deflection of Galvanometer Mm.	Deflection per Degree Mm.
17.75	27.0	9.25	89.0	9.6
"	29.5	11.75	113.0	9.6
"	31.0	13.25	127.0	9.6
"	32.0	14.25	138.0	9.7
"	34.0	16.25	161.0	9.8

Average Deflection per One Degree Difference in Temperature = 9.66 mm.

b) With Variation in Temperature of Both Junctions.

Temperature of Junction 1 Degrees	Temperature of Junction 2 Degrees	Difference in Temperature Degrees	Deflection of Galvanometer Mm.	Deflection per Degree Mm.
30.2	30.6	0.4	4.5	11.1
24.8	30.2	5.6	52.0	9.3
21.8	30.0	8.3	80.0	9.8
19.2	30.0	10.8	103.0	9.5
17.0	29.9	12.9	122.0	9.4
16.0	29.8	13.8	130.0	9.5
13.5	29.2	15.7	154.0	9.8
12.0	29.0	17.0	164.0	9.7
11.0	28.8	17.8	173.0	9.7
9.0	28.8	19.8	191.0	9.8

Average Deflection per One Degree Difference in Temperature = 9.76 mm.

of one degree was not always observed. Still, repeated observation showed that the variation was not more than 2%, and since this meant an error of but little more than one-fifth of a degree, the method was deemed sufficiently accurate for the present purpose.

From more than 250 such observations, the value of the deflection per one degree difference was finally fixed upon as 9.5 mm. but this value was repeatedly checked, sometimes daily for several days in succession.

In determining, therefore, what the temperature within the depression cell was at any given moment, the thermometer which registered the temperature inside of the Pfeiffer stage was read, and the deflection of the galvanometer at that instant was noted. The thermometer reading was then corrected by means of the formula,

$$T_c = T_s \pm \frac{G}{9.5}$$

where T_c = the temperature of the medium in the depression cell.

T_s = the temperature of the water in the stage.

G = the deflection as read on the galvanometer scale.

It is obvious that the arrangement of the apparatus gave information, too, as to whether the circulating water was warmer or colder than the culture medium in the depression cell; for this could be learned from the sense of the deflection, to the right or to the left of the zero point of the scale. Hence, the correction depending upon these conditions, was either plus or minus.

Table II shows the fluctuations of temperature in the depression cell as determined by the method outlined above. In the first column is given the number of the observation; in the second, the time at which the

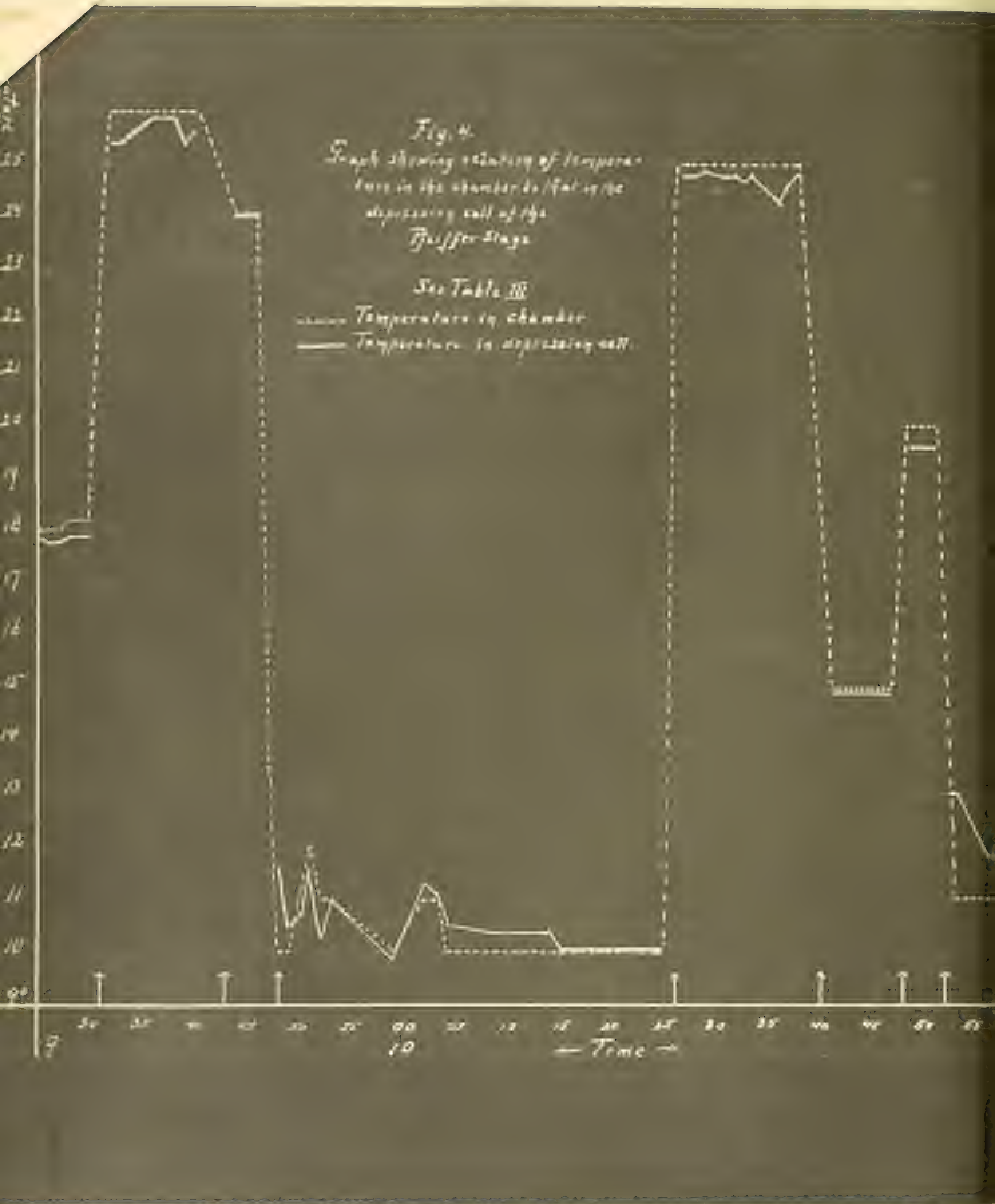


Fig. 4.
Graph showing relation of temperature in the chamber to that in the depressing cell of the Pfeiffer Stage.

See Table III

TABLE II

Comparison of the Temperature in the Water Chamber with that in the Depression Cell

Observation	Time	Temperature of the Water in the Chamber	Temperature of the Medium in Depression Cell	
1	9:25	18	17.9	
2	9:26	"	17.8	
3	9:27	"	17.8	
4	9:28	"	17.9	
5	9:29	"	17.8	
6	9:30	"	17.8	Temp. changed, 9:31
7	9:32	26	25.4	
8	9:33	"	25.4	
9	9:34	"	25.7	
10	9:35	"	25.8	
11	9:36	"	25.9	
12	9:37	"	25.9	
13	9:38	"	25.9	
14	9:39	"	25.4	
15	9:40	"	25.6	Temp. changed, 9:43
16	9:44	24	24.0	
17	9:45	"	24.0	
18	9:46	"	24.0	Temp. changed, 9:46
19	9:48	10	11.66	
20	9:49	"	10.55	
21	9:50	11	10.8	
22	9:51	12	11.6	
23	9:52	11	10.23	
24	9:53	11	11.00	
25	9:59	10	10.0	
26	10:02	11	11.33	
27	10:03	"	11.1	
29	10:04	10	10.5	
30	10:08	"	10.44	
31	10:11	"	10.4	
32	10:14	"	10.0	
33	10:15	"	"	
34	10:16	"	"	
35	10:18	"	"	
36	10:23	"	"	
37	10:24	"	"	
				Temp. changed, 10:26
38	10:27	25	24.8	
39	10:28	"	24.8	
40	10:29	"	24.9	
41	10:30	"	24.5	
42	10:31	"	24.8	
43	10:32	"	24.8	
44	10:33	"	24.7	
45	10:34	"	24.8	
46	10:36	"	24.2	

Observation	Time	Temperature of the Water in the Chamber	Temperature of the Medium in Depression Cell	
47	10:37	25	24.6	
48	10:38	"	24.8	
				Temp. changed, 10:[illegible]
49	10:41	15	15.0	
50	10:44	"	15.0	
51	10:47	"	15.0	
				Temp. changed, 10:[illegible]
52	10:49	20	19.6	
53	10:51	"	19.6	
				Temp. changed, 10:52
54	10:53	11	13.0	
55	10:57	"	11.8	

observation was made; in the third, the thermometer reading showing the temperature of the water circulating within the chamber; in the fourth, finally, the temperature in the depression cell, found by employing the method for correction. From the data presented in this table, a graph was constructed (Fig. 4). In the graph, time is plotted along the line of abscissas, and temperature along the line of ordinates. The thermometer readings, measuring the temperature of the water within the chamber, are shown in broken lines; the temperature in the depression cell is shown in solid lines. The time at which the temperature of the water circulating within the chamber was changed is indicated by arrows.

By referring to the graph, it will be seen that, on changing temperature, it took the depression cell about one minute to become isothermic with the water circulating within the chamber. Thus, the temperature of the circulating water was changed at 9.31 o'clock, from 18.2 degrees to 26 degrees. At 9.32 o'clock, while thermometer recorded exactly the new temperature, the temperature of the depression cell was 25.4 degrees; at 9.34 o'clock, it was 25.7 degrees; at 9.35, it was 25.8 degrees; at 9.36, it was 25.9 degrees. Then a slight drop occurred in the temperature of the depression cell, to 25.4 at 9.39, and this was followed by a slight rise, to 25.6 degrees at 9.40. Such fluctuations are due, probably, to change in the atmospheric conditions immediately surrounding the microscope. A further study of the graph and the table will also reveal the fact that, in this case, at least, the temperature of the medium in the depression cell never actually reached the temperature of the water circulating within the chamber, but that it approximated it to within .1 degree. When the temperature was changed from 26 degrees to 24 degrees at 9.43 o'clock, the temperature of the depression cell was actually the same as that of the chamber, and the change was effected in one minute. At 10.04 o'clock, in

the course of this same test, the temperature of the depression cell remained consistently about .2 of a degree above that of the chamber for 10 minutes, and only after that interval did the depression cell become isothermal with the chamber.

Further analysis of the graph would seem superfluous, as the features we have just described are repeated for other changes of temperature. From repeated tests, the following points regarding the relation of the temperature in the chamber to that in the depression cell were established:-

(1) When the temperature of the water flowing through the Pfeiffer chamber is changed, the temperature in the depression cell responds immediately.

(2) If the change from the old to the new temperature is not very great, the depression cell becomes isothermal, or very nearly so, within a time interval of less than 1 minute.

(3) If the change from the old to the new temperature is rather great, and the new temperature is considerably different from room temperature, the temperature of the depression cell responds promptly, but still a difference of plus or minus .2 degree may be maintained for quite a long time, perhaps for 10 minutes -- the sign of the maintained difference being dependent somewhat on the prevailing room temperature.

(4) Even if the temperature which it is desired to maintain is considerably above or below room temperature, the cell will sooner or later become very nearly isothermal with the chamber.

(5) Once the cell has assumed the temperature of the chamber, or has approximated it closely, it maintains that temperature fairly constantly, with small fluctuations, however, which may vary from 0 to .5 degrees.

It must be added that the value of our experimental data is not dependent upon the accuracy of these statements, for the reason that the exact temperature was assured for each observation. Greater accuracy could easily

have been obtained by this method, but it would have been useless, as it would have been beyond the experimental accuracy secured in other details of the investigation.

3. Measurement of Time

As the investigation was concerned with the rate of locomotion of amoeba, a reliable method of measuring time was important. During the early part of the work, an Elgin watch was used for this purpose. On account of its small size, however, it was found difficult to read the second hand accurately in a room that was almost dark. A large Wizard Alarm Clock (Wizard Clock Company, New York) was then used. The second hand of this clock was found to be well synchronized with the minute hand. It was found that the second hand preceded or lagged behind the minute hand by not more than 5 seconds in the course of three hours and hence it was thought sufficiently accurate for the purpose of the investigation. The slight angle from which the clock was viewed by the observer from his position at the microscope was kept constant, to obviate the errors that might be introduced by making observations a few seconds too early or too late.

4. Measurement of the Rate Locomotion

The following obvious and simple method for measuring the rate of locomotion was adopted:

a) Under the camera lucida, drawings were made of the posterior end of a moving amoeba at definite time intervals.

b) The distance between these successive drawings was measured.

c) The rate per minute was then calculated.

(a) A series of drawings of the posterior end of a moving amoeba gives us an accurate picture of its path. In Fig. 3 are shown several of such

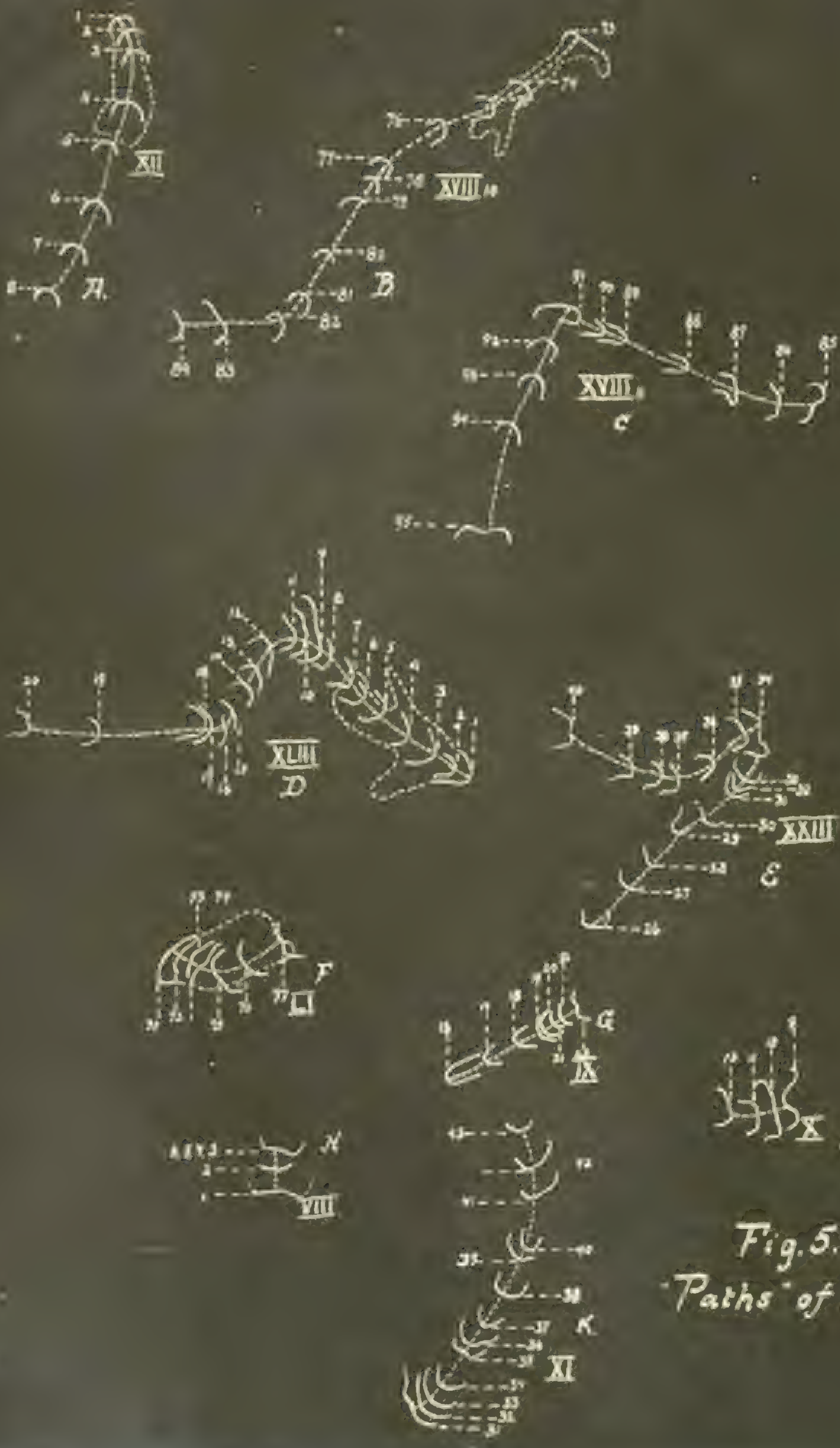


Fig. 5.
"Paths" of Amoeba.

paths, chosen almost at random from the records of this investigation. (The Roman numerals in the figure are the numbers of the individuals as they appear in the records.) In some cases, e.g. A and K, we may find movement almost directly forward in the same direction. In others, e.g. B, C, D, the path is more or less curved. In others again, e.g. E, there is reversal of direction by rather a sharp turn in the path. In still others, there may be complete reversal of direction by making the anterior end the posterior. Path H will show the condition of an animal at rest. In this case, the animal was found in the same place when observations 3, 4, 5 and 6 were made. Path F shows rather a sudden turn in the forward movement, and Path J, the difference one may meet with in the configuration of the posterior end during successive observations. Almost all of the paths here reproduced show considerable variation in rate, some of them of decided range. It is not to our purpose to enter into a discussion of this point here, but the time interval between all of the drawings shown in this figure may be found by reference to the records of these individuals (See Appendix).

The drawings were all made upon sheets of paper of uniform size, 12.8 by 7.6 cm. These sheets will be referred to as record sheets. They were changed at irregular intervals whenever the movement of the individual under observation brought it close to the edge of one of these record sheets, as it was visible under the camera, or whenever it became necessary to change the field of the microscope while following a given individual.

(b) For the purpose of measurement, the drawings in each path were connected by a line which would more accurately define the actual path. A glance at Figure 5 will show how this was done. In some cases, there could be no doubt about the points that should be connected in establishing the

path, e.g. paths A, B, D, H (Fig. 5) are obvious. In other cases, there was some question regarding the exact points through which the line should be drawn. Path K illustrates such a case. This path between observations 31 and 38 might have been made practically a straight line. Generally, however, such difficulties did not introduce an appreciable error into the measurements, as the difference in length between the various paths that might have been drawn and the one actually determined upon, amounted to little more than two or three tenths of a millimeter.

The distances between the successive drawings were measured by laying a flexible steel tape upon the path, and reading off the intervals to the nearest half millimeter.

(c) Finally, the apparent rate was determined by dividing the distance traversed by the time interval elapsing between two successive drawings.

These values gave the "apparent" rates as they were seen on the drawing board. They were found to be magnified 64 times. They were not reduced to actual rates, however, to obviate the difficulties incident upon the use of long fractions. In the following pages, therefore, when a given rate is mentioned, it must be understood that we are speaking of an apparent rate, and that the real rate may be found by dividing the apparent rate by 64. Thus, a rate of 5 mm. per minute is really an actual rate of .078 mm. per minute. To make further reference to this matter unnecessary, the following brief table is appended to facilitate comparison of apparent with actual rates (See Table III).

T A B L E III

Reduction of Apparent Rates to Actual Rates.

Apparent Rate as Projected by Camera. Mm. per Min.	Actual Rate Mm. per Min.
1	.0156
2	.0312
3	.0461
4	.0624
5	.0780
6	.0936
7	.1092
8	.1248
9	.1394
10	.1560
11	.1717
12	.1875
13	.2028
14	.2184
15	.2340
16	.2596
17	.2652
18	.2788
19	.2954
20	.3120

5. Method of Recording Results

The results of the observation were recorded in tables in which the following items may be found (See Appendix):

In Column 1 are recorded the numbers of the observation. It will be found that for the most part they are successive. For the sake of saving space, however, some of the observations were dropped, when, for example, some doubt arose regarding the accuracy of an observation, or when the animal remained for a protracted length of time in the same position. It was felt to be useless to overburden the tables with these details.

In Column 2 is recorded the time at which an observation was made. Usually, some effort was made to make these observations on the even minute or half minute, but at times this was not possible.

In Column 3 are recorded the time intervals between two successive observations. It will be noted that whenever a record sheet was changed or a new starting point had to be taken, owing to an accidental shift of the Pfeiffer stage or for some other reason, the interval is entered as a zero interval, and the succeeding observation is calculated from this zero time. In a few places, zero time is mentioned in the last column among the remarks, especially after a resting period.

In Column 4 are entered the temperatures. These are the corrected temperatures, in other words, the temperatures within the depression cell of the stage, as found by the methods described in a preceding section. In the original records of the experiments, there were entered in three separate columns, (a) the reading of the thermometer, giving the temperature within the chamber of the Pfeiffer stage; (b) the deflection of the galvanometer at the time at which the observation was made; (c) the temperature of the thermometer corrected by the temperature-difference value of the galvanometer deflection. It would have been useless and cum-

fusing, however, to burden the tables with these further details.

In Column 5, the distance traversed by the animal between two successive observations is recorded. In this case, too, zero distance is recorded whenever, for reasons already mentioned, a record sheet was changed, or a new starting point was taken.

In Column 6, the average rate, per minute, found by dividing the value in Column 5 by that in Column 3, is recorded.

In the last column, details of manipulation are given, chiefly those pertaining to the changes in the record sheets and to changes of temperature. At times, remarks are made about the behavior of the animal under observation, but such details were generally regarded as simply burdening the tables with irrelevant matter and, consequently, many of the remarks that were noted in the original records have been omitted.

6. Graphic Method for Representing Rates of Locomotion

Amoeba shows so great and so frequent variations in the rate of its locomotion that it is difficult to form an adequate conception of its behavior from a series of figures such as are given in the rate-column of the performance records. It was thought desirable, therefore, to represent the variations in rate graphically. Accordingly, a performance graph was constructed for each individual. Photostat copies of the original graphs will be found in the appendix to this dissertation. Each of these copies is .6 of the size of the original.

The graphs are all drawn in the same manner and to the same scale. The independent variable, time, is plotted along the line of abscissas. In the originals, 2 mm. along this line represented 1 minute. Along the line of ordinates are plotted both temperature and the rate of locomotion. This arrangement enables one to see at a glance the influence of temperature upon the rate of locomotion, both, at the instant when the temperature is changed and at any point of time or for any time-period, under constant temperature conditions.

The temperature is shown in red in all of the graphs. In the original graphs, 1 cm. represented 1 degree, but, as has been said, the scale was reduced to .6 of the original in the reproductions.

The rate per minute is shown in white in all of the graphs. In the original graphs, 1 cm. represented a variation of .5 mm. in rate. The rates are plotted as plateaus rather than as peaks, as it is much easier in this way to see at a glance how long a given rate was maintained. These plateaus are then connected by vertical lines to make the variations in rate more obvious. In some of the graphs, breaks in the series of

observations are indicated by broken lines, but in others, the various parts of the curves are left discontinuous to avoid possible confusion. It was also thought advisable for the purpose of simplifying the graphs to indicate periods of rest merely by writing the word "Rest" on the graph, than to follow the more logical procedure, of bringing the ordinates down to the line of zero movement.

7. Exclusion of Factors Except Temperature, Which Affect the Rate of Locomotion

The rate of locomotion in amoeba is determined, probably, by many factors. Internal factors, such as age, size and nutritional condition, of the organism, and environmental factors, such as the chemical constitution of the medium, the physical density of the medium, light conditions, and temperature, must all have their influence on locomotor activity. Some effort had to be made, therefore, to equalize the influence of all of these factors, except that of temperature, on the various individuals that were studied.

a) Age. This factor could not be controlled satisfactorily. The effort to keep isolation cultures was given up, as this method of securing material was found to be too uncertain. It is probable, therefore, that individuals of very varied age were used in this investigation.

b) Size. Size affects the absolute rate of an individual, but it may be doubted whether size alone affects the relative rate, i.e. the ratio of two rates at different temperatures. Considerable effort was made to secure individuals that were fairly large and as uniform in size as possible -- at least in their appearance in the optical plane of the microscope.

c) Nutritional Conditions. Our treatment of nutritional conditions as a factor affecting the rate of locomotion has already been hinted at in a previous paragraph. The fact that during the progress of the investigation so few individuals were found that were feeding during their resting stages, even though abundant food was available, is taken as

an indication that the nutritional condition of the amoebae was good, and hence this factor might be considered as fairly well equalized in the various individuals that were studied.

d) Chemical Constitution of the Medium. This was controlled by treating the various cultures in the same way, by supplying equal quantities of hay and spring water, and by exposing them to the same conditions of temperature and atmospheric environment.

e) Physical Density of the Medium. It was found to be quite impossible to remove from the depression cell all the obstructions, such as plant debris, which might hinder the free movement of the amoebae. The statement will be found rather frequently in the remark column of the performance records, that an individual "crawled under debris". All that could be done in such circumstances was to wait until the animal should emerge. Considerable attention was given to accuracy in this matter.

f) Light. Light intensity and, probably, the quality of the light have considerable effect upon the rate of locomotion. The influence of this factor was rendered uniform for all the individuals by working in a darkened room that was illuminated by only an old-type, carbon-filament, 32 candle-power bulb, which was kept at the same distance, 60 cm., and at the same angle relative to the mirror of the microscope, during all the experiments. The diaphragm of the microscope was closed to its smallest aperture and the blue ray filter was inserted in the substage throughout the whole investigation. With this attention to light conditions, it is felt that all the individuals experimented upon were subjected to the same light influence.

8. The Assembled Apparatus.

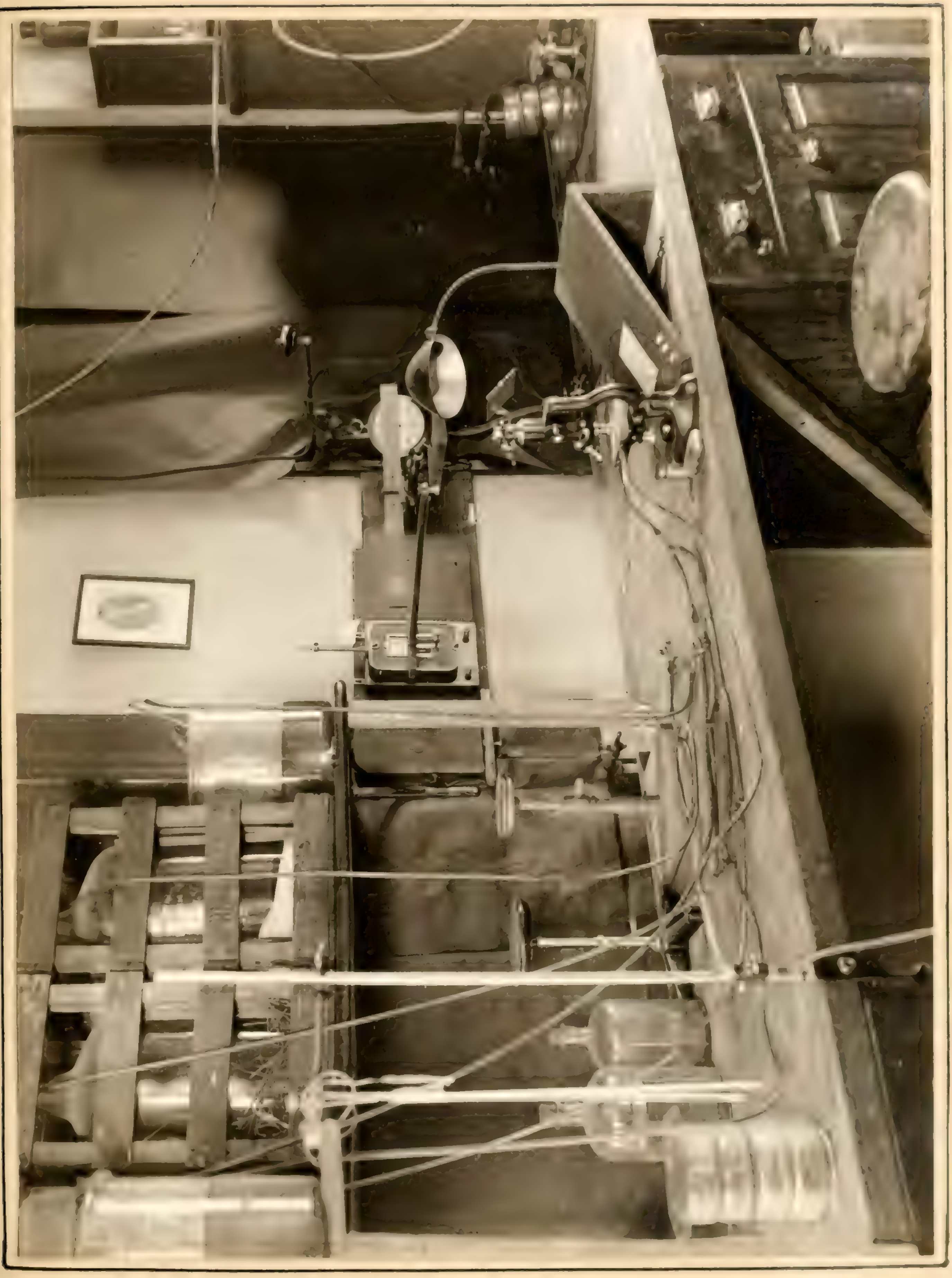
The assembled apparatus as described in the preceding sections are shown in Fig. 6. The letters to be found on the key-sheet of the photograph signify,

C, Clock. R, Reservoirs.

D, Drain from the Warming Stage. S, Warming Stage.

G, Galvanometer. T_1, Delivery Tubes with Stop Cocks.

M, Microscope with Camera Lucida. T_2, Telescope for Reading Galvanometer.



PRESENTATION OF THE DATA.

Prefatory Remarks.

1. The General Conclusions.

2. Division of the Subject.

Part I.

LOCOMOTION OF AMOEBA AT CONSTANT TEMPERATURE.

Part II.

LOCOMOTOR RESPONSE OF AMOEBA TO CHANGING TEMPERATURE.

Part III.

THE MEASURE OF THE DEPENDENCE OF LOCOMOTION ON TEMPERATURE.

REMARKS PREPARATORY TO THE PRESENTATION OF THE EXPERIMENTAL DATA

1. The General Conclusions.

A brief statement of the general conclusions from this investigation will, probably, be of assistance in following the trend of the data about to be presented. Such a summary in the early part of this paper is the more desirable, as the impression may easily be conveyed that it is useless to formulate a general statement concerning the dependence of locomotion on temperature, owing to the great variations in the rate of locomotion of individual amoebae and the wide divergencies of behavior which they exhibit. So marked are these variations in certain individuals that, from a study of them, one might be lead to deny any relation whatever between rate of locomotion and temperature. Not only certain individuals at different temperatures, but different individuals at the same temperature, as well, exhibit this great variability. A study of the average rates of locomotion in the entire mass of data, however, reveals the actual existence of a dependence. From a study of these averages, it was found, that,

1) The rate of locomotion of amoeba is dependent on temperature.
2) The rate of locomotion increases with rising temperature from, approximately, 5 degrees, the temperature at which no movement was observed, to, an optimal value at, approximately, 22.5 degrees.
3) Beyond this temperature, the rate of locomotion decreases, probably, to the lethal point, at about 33 degrees.
4) The dependence of the rate of locomotion on temperature is such that for averages its measure can be expressed as a temperature coefficient, in the van't Hoff sense, of between 2.4 and 1.80 over the entire range of temperatures used in this investigation.

2. Division of the Subject.

It would seem logical to divide our subject in such a way as to substantiate in successive chapters the general conclusions just enunciated. For several reasons, however, this course was not followed. In the first place, it appeared desirable to describe at some length various phenomena associated with locomotion at constant temperature. Several such phenomena emerged from this intensive study of the rate of locomotion, and as no reference to them has been found in the literature they will be treated at some length. Moreover, before we discuss the influence of varying temperature on rate of locomotion, we ought to have as full a detailed knowledge as possible of the locomotion at a constant temperature, and of the changes of rate that may take place in such a constant condition. It is for these reasons that we have divided our subject as follows:

Part I. Locomotion at constant temperature.

Part II. Locomotor response to changing temperature.

Part III. The measure of the dependence of the rate of locomotion on temperature.

PART I

LOCOMOTION OF AMOEBA AT CONSTANT TEMPERATURE

1. A Typical Performance Record.
2. Some Features of Locomotion at Constant Temperature.
   - A. Variability in Rate.
     - a) Periods of Locomotion.
     - b) Periods of Rest.
     - c) "Fast" and "Slow" Individuals.
   - B. Types of Locomotion Relative to Changes of Rate.
     - a) Locomotion at Uniform Rate.
     - b) Locomotion at Suddenly Accelerated or Suddenly Retarded Rate.
     - c) Locomotion at Gradually Accelerated or Gradually Retarded Rate.
     - d) Locomotion at Alternately Accelerated and Retarded Rate.
   - C. The Rhythmic Character of Locomotion.
     - a) The Short-period Rhythm.
     - b) The Constancy of the "Ratio of Rates".
     - c) The Long-period Rhythm.
3. A Discussion of Certain Features of Locomotion at Constant Temperature.

1. A TYPICAL PERFORMANCE RECORD

A somewhat detailed description of the locomotor activity of an ameba at constant temperature may prove helpful for the ready understanding of all that is to follow. We have selected Individual XII for the purpose of this description, not only because this individual was observed for the comparatively long period of two hours, during which time interval the characteristic features of its locomotion could be ascertained, but also because during the series of observations on this particular animal certain observational difficulties were encountered, a description of which will probably not be without value for the further reading of this paper. The performance record (Table IV) and the performance graph (Fig. 7) for this individual are here inserted for the purpose of rendering the description more intelligible. -- It must be borne in mind that when we speak of rates in this section, we mean the rates as viewed under our optical system, sc. under a magnification of 64.

Individual XII, when placed in the depression cell of the Pfeiffer stage at 9.50 A.M., became attached to the bottom of the cell almost immediately and began to move promptly. The thermometer in the chamber of the stage at this time registered 19.5 degrees and this temperature was maintained throughout the two hours during which this series of observations was made. The galvanometer, however, indicated that the temperature in the depression cell fluctuated slightly between limits that were well within half a degree above and below the temperature of the chamber. As has been found from repeated experimentation, however, Ameba does not react in an appreciable way to such fluctuations when the prevailing temperature is very close to that of the environment in which the animal had been kept for some time. As Individual XII had been kept in a culture at a room temperature of about 20 degrees, we may safely


XII
Temperature Varied

T A B L E IV

PERFORMANCE RECORD OF INDIVIDUAL XII

No. of Observation	Time	Time Interval Min.	Temperature Degrees C	Total Distance Mm.	Rate Mm. per Min.	Remarks
1	9:55	0	19.5	0	0	
2	9:56	1	"	3	3	
3	9:57	1	"	4	4	
4	9:58	1	"	8	8	
5	9:59	1	"	9	9	
6	10:00	1	"	11	11	
7	10:01	1	"	9	9	
8	10:02	1	"	9	9	Animal under debris
9	10:16	0	"	0	0	New record sheet
10	10:17	1	"	7	7	
11	10:18	1	"	3	3	
12	10:19	1	"	3	3	
13	10:20	1	"	4	4	
14	10:21	1	"	8	8	
15	10:22	1	"	8	8	
16	10:23	1	"	11	11	
17	10:24	0	"	0	0	New record sheet
18	10:25	1	"	8	8	
19	10:26	1	"	7	7	
20	10:27	1	"	9	9	
21	10:28	1	"	4	4	
22	10:29	1	"	3	3	
23	10:30:05	1.08	"	8	7.4	
24	10:31	0.9	"	8	8.8	
25	10:32	1	"	4	4	
26	10:33	1	"	5	5	
27	10:36	0	"	0	0	Interruption New record sheet
28	10:37:05	1.08	"	4	3.7	
29	10:38:10	1.08	"	5	4.6	
30	10:39	0.83	"	7	8.4	
31	10:40:10	1.16	"	7	6	
32	10:41	0.83	"	7	8.4	
33	10:42	1	"	8	8	
34	10:43	1	"	10	10	
35	10:44	1	"	5.5	5.5	
36	10:45	1	"	9	9	Rest; began to move, 10:50
38	10:50	0	"	0	0	New record sheet
39	10:51	1	"	5	5	Animal dragging debris
40	10:52	1	"	3.5	3.5	" " "
41	10:53	1	"	3.5	3.5	" " "
42	10:55	0	"	0	0	No observations made
43	10:56	1	"	3	3	Animal dragging debris
44	11:07	0	"	[illegible]	0	Animal under debris until 11:07

No. of Observation	Time	Time Interval Min.	Temperature Degrees C	Total Distance Mm.	Rate Mm. per Min.	Remarks
46	11:11	4	19.5	6.5	1.6	
47	11:16	5	"	7.5	1.5	Change of direction
48	11:21	5	"	9	1.8	
49	11:23	2	"	6	3	
50	11:25	2	"	7	3.5	
51	11:27	2	"	7.5	3.8	
52	11:29	2	"	10	5	
53	11:30	1	"	9	9	
54	11:31	1	"	5	5	
55	11:32	1	"	5	5	
56	11:32:30	0	"	0	0	New record sheet
57	11:33	0.5	"	5	10	
58	11:34	1	"	9.5	9.5	
59	11:35	1	"	6	6	
60	11:36	1	"	4.5	4.5	
61	11:38	2	"	5.5	2.8	
62	11:40	2	"	5	2.5	
63	11:42	2	"	10	5	
64	11:43	0	"	0	0	New record sheet
65	11:45	2	"	10	5	
66	11:47	2	"	9.5	4.8	
67	11:50	3	"	9	3	
68	11:52	2	"	15	7.5	
69	11:53	1	"	3	3	
70	11:55	2	"	6	3	
71	11:57	2	"	6	3	
72	11:59	2	"	6	3	
73	12:01	2	"	5	2.5	

assume that the slight fluctuations in temperature that were observed in the course of this experiment had little effect in determining the rate of locomotion.

The amoeba was measured shortly after it had been put upon the stage. It was found to be 340 μ in length. Its anterior end was rather pointed, its posterior end rather broad and blunted, and its sides were rather bulging. It soon changed in shape, however, and was gradually assuming an elongated mono-podal shape which is characteristic of amoebae moving at a high rate. At this time, no secondary pseudopods were being formed.

An occasional glance at the performance graph (Fig.7) will enable the reader to follow more closely the changes of rate which we are now about to describe. When the observations began, 5 minutes after the animal had been put upon the stage, the amoeba was moving at a rate of 3 mm. per minute. During the next four minutes, this rate increased gradually to 4, 5, 8, and 9 mm. per minute, and during the fifth minute the rate reached a maximum value of 11 mm. per minute. The rate then decreased, the animal moving at a rate of 9 mm. per minute for the next two minutes.

The amoeba now encountered a mass of plant debris, crawled under it and was lost to view from 10:02 to 10:16 A.M. When it emerged from the debris, its direction of movement was inclined at an angle of about 45 degrees to its previous direction. As may be seen from the graph, there now followed, for 17 minutes from 10:16 to 10:33 A.M., a series of alternate accelerations and retardations of rate, some of them sudden, others more gradual. In one of these accelerations, the rate again reached its previous maximum of 11 mm. per minute, but this high maximum was followed by a gradual diminution in the magnitude of the accelerations.

The minimum rate during this period did not fall below the previous minimum of 3 mm. per minute.

At 10:33 A.M., some manipulation of the reservoirs became necessary and the record sheet had to be changed, these operations consuming three minutes.

When the observations were resumed, the amoeba was moving at a rate of 3.7 mm. per minute. Another series of successive alternations and retardations now ensued, the rates being determined every minute for 8 minutes. The maximum rate attained during this interval was one of 10 mm. per minute. A glance at the graph will, in fact, suggest a gradual slowing down of the rate. This phenomenon, as well as others which have been mentioned in this description, will be discussed below.

Between the rates of 6 and 10 mm. per minute (see graph), while the animal was moving at a rather high rate of 8.4 and 8 mm. per minute, the direction of movement changed through an angle of almost 90 degrees, and a "lunge" forward took place almost as soon as the animal had assumed the new direction. This instance effectively contradicts an impression that may be formed from constant observation of Amoeba, that changes in rate seem to be correlated in some way with changes of direction, and that the animal must necessarily slow down while it pursues a curved path and accelerates its rate when it is moving straight forward.

During the next five minutes, the amoeba rested, contracting to almost half its former greatest length, namely to 190 . When it resumed its locomotor activity at a rate of 5 mm. per minute, it was dragging some plant debris, and its rate was slowed down to 3.5 mm. per minute for two minutes. It was again lost sight of for 10 minutes under a mass of plant debris.

When it re-emerged from the debris, the amoeba almost retraced its former path, and continued in the new direction along a path that was slightly sinuous, for the rest of the time during which it was under observation. At first its rate was rather slow, being only 1.5 mm. for four minutes, then 1.5 mm. for five minutes and then 1.8 mm. for the next five minutes. Then, however, a period of gradual accelerations began, as is clearly shown by the performance graph. The rate began to "climb" at first to 3, then to 3.5, then to 3.8, then to 5 and finally to 6 mm. per minute. A retardation followed in which the animal was moving at a rate of 5 mm. per minute, and this in turn was followed by a rather sudden "lunge", during which a maximum of 10 mm. per minute was attained. The rate now decreased gradually, being successively, 9.5, 6, 4.5, 3.5 and 2.5 mm. per minute. The graph shows that this succession of rates must be interpreted as another "wave" in the locomotion, a gradual increase to a maximum, and a corresponding decrease to a minimum of rate. Again, there was a rapid acceleration during which the amoeba sustained a rate of 5 mm. during five minutes, and this period of uniform motion was followed by a slight fall in rate to 4.8 mm. per minute and a greater one to 3 mm. per minute, but all this was preparatory to a "spurt" during which the amoeba reached a rate of 7.5 mm. and sustained it for two minutes. During the next 7 minutes a uniform rate of 7.5 mm. per minute was kept, and when the series of observations was discontinued, the amoeba was moving at a rate of 2.5 mm. per minute.

This account of the locomotor activity of an amoeba during a period of somewhat more than 2 hours may be considered fairly typical of the activity of all the other individuals that have been studied. By comparing the performance records and graph of Individual A11 with those of the other individuals (see Appendix), it will be seen that some of the amoeba rested for a

longer time, others were active for a longer time; that some attained much higher rates, others moved at lower rates; that changes of rate were more sudden in some cases, in others much less so. In general, however, a comparative study of the graphs will emphasize three features of locomotor activity, which we are now to treat of at a greater length,

A. Variability in the rate of locomotion at constant temperature.

B. The various types of locomotion relative to change of rate.

C. The rhythmic character of locomotion.

2. SOME FEATURES OF LOCOMOTION at CONSTANT TEMPERATURE

A. VARIABILITY IN RATE

a) Variability of Rate During Periods of Locomotion.

The description we have just given of the behavior of Individual XII at constant temperature illustrates, first, the variability of the rates of locomotion. -- The relation of temperature to the rate of locomotion cannot be thought of in the sense that temperature determines absolutely at what rate an amoeba must progress. Temperature may fix a maximum rate which may not be exceeded by an individual at that particular temperature, but below this maximum, Amoeba may move at various rates. This will become abundantly clear from even a casual inspection of the performance records. We have seen that Individual XII did not exceed a rate of 11 mm. per minute at a temperature of 15.5 degrees, but, between that maximum rate and complete rest, the animal assumed about 25 other rates, some sustained for a short period, others for a lengthy period. To choose another example at random, Individual XLIV, in the 20 minutes during which it was kept at 18 degrees, was moving at rates of 6, 7, 7.5, 4.5, 3.5, 1.5, 2, 6.5 and 1 mm. per minute, in 9 successive minutes. The same fact may be illustrated by a comparison of the rates of locomotion of different individuals, all at the same temperature. Table V, excerpted from the records, enables us to make such a cursory comparison. The table shows the maximal, the minimal and the average rates of locomotion of eight individuals all at 20 degrees, in columns 3, 4 and 5 respectively. Column 1 gives the designation of the individual. Column 2 is inserted to give some idea of the length of time during which such variations in water may occur, and in Column 6 is given the number of

T A B L E V

Different Rates of Locomotion
of
Several Amoebae at 20 Degrees

1 Individual	2 Duration of Observation Min.	3 Maximum Rate per Minute Mm.	4 Minimum Rate per Minute Mm.	5 Average Rate per Minute Mm.	1 Number of Different Rates
XIII	63	5.5	0.7	2.35	15
XIV	30	2.25	0.5	1.25	8
XVI	48	14.0	0.5	2.09	17
XX	54	8.5	0.8	2.46	16
XXX	31	13.0	1.5	6.33	16
XXXIII	30	5.0	1.5	3.46	6
XXXVI	33	14.0	5.0	7.40	11
XLIII	33	10.0	1.0	3.60	14

different rates which were found to lie between the maximal and the minimal rate. Thus, for example, Individual XIII, during the period of 63 minutes during which it was observed at a temperature of 20 degrees, moved for a time with a maximum rate of 5.5 and a minimum rate of 0.7 mm. per minute. Between these maximal and minimal rates, 13 other rates were definitely measured, namely rates of 0.8, 1.0, 1.3, 1.5, 2.0, 2.4, 3.0, 3.5, 4.0, 4.3, 4.5, 5.0 and 5.5 mm. per minute. A reference to the performance graphs of these particular individuals will lend emphasis to this feature of behavior.

It will be seen from the table, that the maximal rates attained at 20 degrees varied between 14.0 and 2.25 mm. per minute, the minimal rates, between 5.0 and 0.5 mm. per minute, and the average rates during the periods of observation, between 7.4 and 1.25 mm. per minute, in these eight individuals. In selecting them, no effort was made to present extreme examples.

The conclusions seem justified that,

(1) there is no fixed rate at which an individual must move at a given temperature,

(2) at the same temperature, different individuals may move with decidedly different maximal, average and minimal rates.

b) Variability of the Length of the Resting Periods.

Closely associated with the feature of locomotor behavior now being discussed, is the length of the resting periods. The all but ceaseless locomotor activity of most of the amoebae that were studied, is one of the most striking characteristics in the behavior of this organism. In some of the series of observations, an individual was followed for as long as four hours, and in that length of time the resting periods all added together, amounted to little more than 20 minutes. In some of these cases, the animal was subjected to various temperatures, and it is possible that the stimulation imparted by this change of external condition shortened the periods of rest. But in other cases in which the amoeba was followed for two hours at constant temperature, the periods of rest were no less surprisingly short. The extent of variation of the length of the resting period, as well as its independence of temperature, may be illustrated by a few instances chosen at random. Table VI gives a few of such instances.

The meaning of the table is probably obvious. In the first column is given the designation of the individual amoeba. Column 2 gives the duration of the observation at the stated constant temperature. Column 3 gives the temperature at which the observations were made. Column 4 gives the duration of the periods of locomotion, all added together. Column 5 gives the duration of the periods of rest all added together. Column 6 gives the relation in percent of the duration of rest to the total duration of the observations.

It will be seen that these four individuals were observed for a sufficiently long period of time to give one a fair knowledge of their locomotor behavior. Moreover, the data is presented for four different temperatures, namely for 18, 19.5, 20 and 25 degrees. In three cases

TABLE VI

Duration of the Periods of Rest

Individual	Duration of Observation at given Temperature	Temperature Degrees C	Duration of Movement Min.	Duration of Rest Min.	Rest Period % of Duration of Observation
L	45.5	18	42	3.5	7.7
XII	92.9	19.5	88.9	5	5.4
XX	80.5	20	52.5	28	34.8
XXII	57.5	25	55.5	2	3.6

the periods of rest were extremely brief, only 3.6, 5.4 and 7.7 % of the total duration of the observations, while in the fourth, the animal was resting during 34.8% of the time during which it was under observation.

In general:

(1) The resting periods in Amoeba were found to be extremely brief.

(2) At times, an individual shows little locomotor activity during long periods of time.

(3) Amoeba may rest for a prolonged period at almost any temperature.

(4) Amoeba is more likely to rest when the temperature is low than when it is high; unless the high temperature exceed the physiological optimum, when the periods of rest may be prolonged.

c) "Fast" and "Slow" Individuals.

Despite all that we have said about the variation in the length of the periods of locomotor activity and of rest, it still remains true that different individuals manifest consistently a characteristic which might enable us to classify them as "slow" or "fast". These designations characterize not merely their comparative rates, but also their periods of activity and inactivity in locomotion. It would be difficult to present in condensed form data which would substantiate this statement. Table VII will emphasize the contrast. All the individuals listed in this table were observed at 20 degrees. The designation of the individual is given in Column 1, the range of rates at which the animal moved is given in Column 2, and the average rate of locomotion during the period during which the animal was under observation, is given in Column 3. Individual XIV with an average rate of only 1.24 mm. per minute might be characterized as "slow", while Individual XXIV, with an average rate of 9.5 mm. per minute, is decidedly "fast".

The fact, however, that an animal moves slowly or rapidly at one temperature does not imply that it exhibits the same characteristic at another temperature. Table VIII illustrates the point. In this table the rates of four individuals at 10 and 20 degrees are compared. Individual XIV which moved at a slow average rate of 1.24 mm. per minute at 20 degrees moved with a correspondingly slow rate of 0.60 mm. per minute at 10 degrees. Individual VI maintained rates at these two temperatures which must be considered fast. But Individual XVI which moved at a slow rate at 20 degrees, moved at almost the same rate at 10 degrees, and a rate of 2.00 mm. per minute must be considered fast for this low temperature.

T A B L E VII

"Fast" and "Slow Individuals.

At 20 Degrees.

Individual	Range of Rates Mm. per Min.	Average Rate Mm. per Min.
XIII	0.7 - 6.5	2.36
XIV	0.5 - 2.3	1.24
XXIV	2.0 - 16.0	9.5
XXXVI	4.0 - 14.0	7.6

T A B L E VIII

"Fast" and "Slow Individuals.

At 10 and 20 Degrees.

Individual	Average Rate	
	At 20 Degrees	At 10 Degrees
XIV	1.24	0.60
XVI	2.40	2.00
V	8.20	1.50
VI	10.60	1.34

General Conclusion Regarding the Variability in Rate of Amoeba, at Constant Temperature.

From all that has been said under this heading, it will be clear that amoeba shows a marked variability in its rate of locomotion under conditions not only of changing but also of constant temperature.

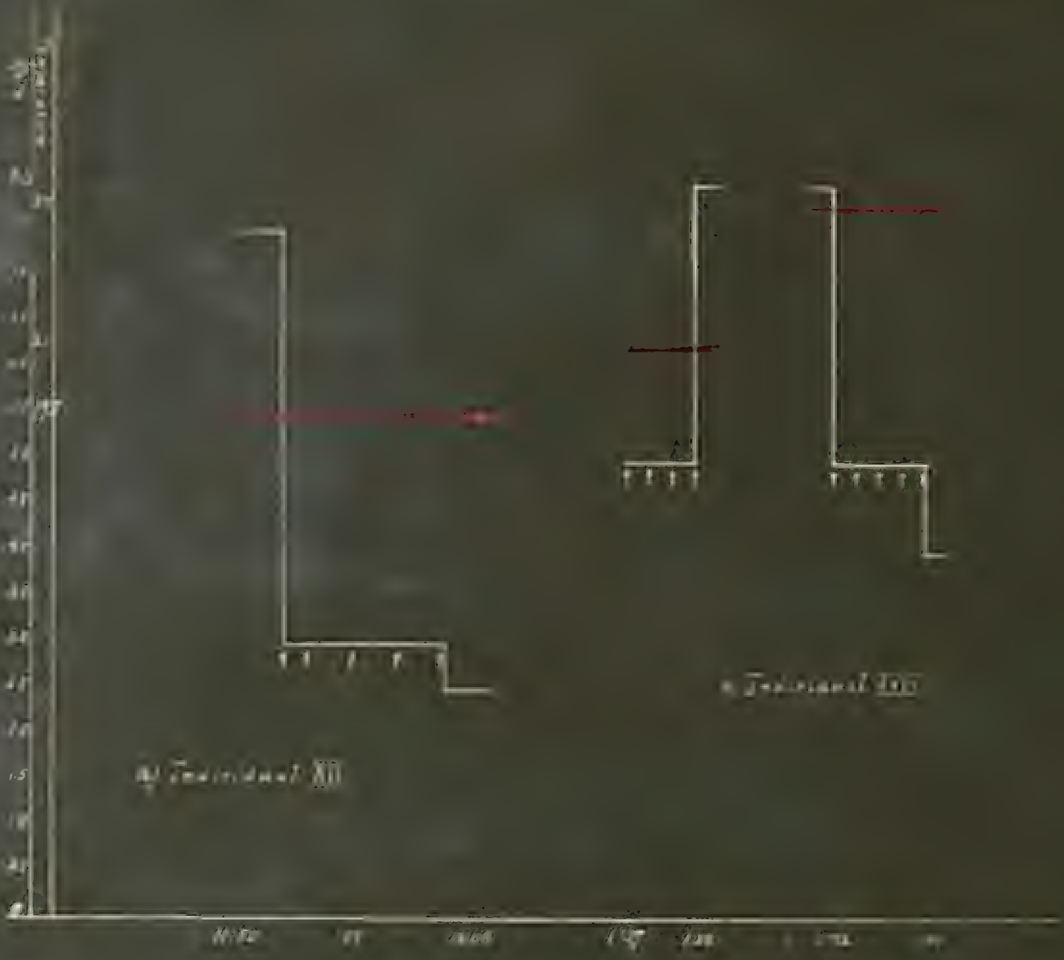


Fig. 8
To illustrate Uniform Motion in Amoeba
(The arrows indicate moments at which observations were made)

B. TYPES OF LOCOMOTION RELATIVE TO RATE

A second feature of the locomotor activity of Amoeba, which becomes apparent from a comparative study of the performance graphs, is the variation in the relation to each other of successive rates. Amoeba may progress,

a) at a uniform rate;

b) at a suddenly accelerated or suddenly retarded rate;

c) at a gradually accelerated or gradually retarded rate;

d) at a rate which is alternately accelerated and retarded.

a) Locomotion at Uniform Rate.

Individual XII, the behavior of which at constant temperature has been described at length, (p. 42) affords an illustration of this mode of locomotor activity. From 11:52 to 11:59 this amoeba moved at a uniform rate of 3 mm. per minute. (Figs. 7 and 8a). During this time interval, four observations were made, at 11:53, 11:55, 11:57 and at 11:59 o'clock and each observation showed that the rate had remained constant. This uniform rate was, therefore, sustained for 7 minutes.

Such a uniform rate of locomotion is comparatively rare. It occurs in some individuals, however. Thus Individual XXVI (Fig. 8,b) sustained a uniform rate of 5 mm. for 3 minutes, from 1:17 to 1:20 o'clock, and, again, for 4 minutes from 1:42 to 1:46 o'clock, the observations having all been taken at minute intervals. A uniform rate of locomotion is never sustained for very long, however, the period of 7 minutes in the case of Individual XII being the longest one on record.

In making these statements regarding uniform locomotion in Amoeba, we must not overlook the fact that our method of observation may be faulty, insofar as the detection of very slight fluctuations is concerned.

If minimal fluctuation in rate occur with greater frequency than the frequency of our observation, they will escape notice. There is, in fact, some evidence that such very sudden, though slight, variations in rate do occur.

When an amoeba is moving very slowly, it was found to be necessary to allow a time interval of more than one minute to elapse between observations. For locomotion may, at times, be so greatly retarded, that, under the magnification employed in this investigation, the animal may seem to be at rest. Five or even ten minutes were, therefore, allowed to elapse between successive observations, as otherwise the drawings that were made to establish the path of the amoeba would have been so crowded that no accuracy of measurement could have been secured. Individual XXXV (Fig. 8,c) illustrates the point. An observation was made on this individual at 2:00 o'clock while the temperature was 9.5 degrees, and nine minutes were allowed to elapse between this and the next observation. During this time interval the animal had moved a distance of 3.5 mm., at a rate, therefore, of .4 mm. per minute. This rate might have been uniform but it is quite probable that slight fluctuations occurred that were not detected. In the records, therefore, this individual is described as having shown a uniform rate for 9 minutes, but only because the average rate for 9 minutes was determined. In the case of Individuals XII and XXVI, we are much more sure of the uniformity of the rate sustained during the time interval stated, as the observations were taken with much greater frequency.

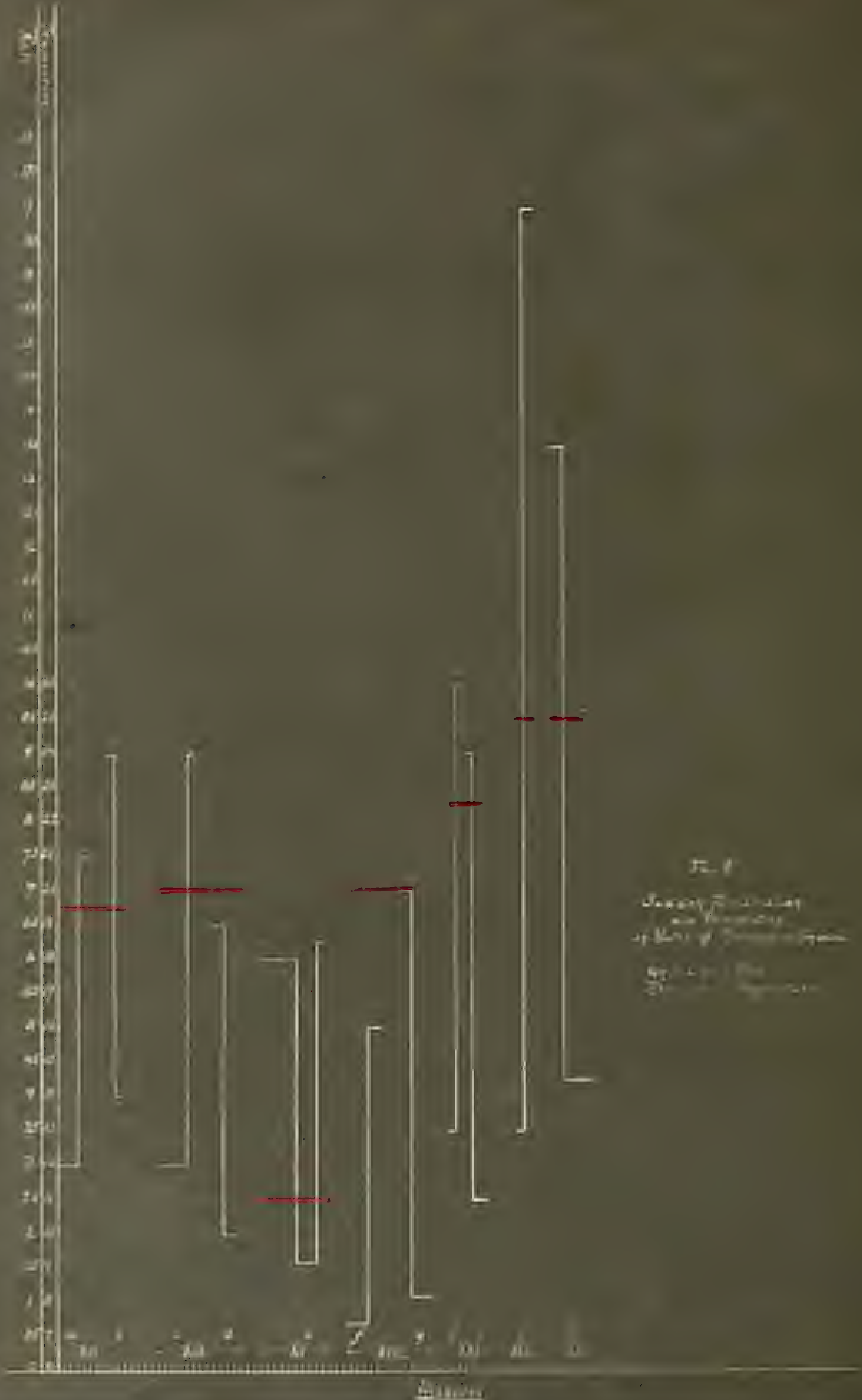
Our conclusions regarding locomotion at uniform rate are not based upon cases like that of Individual XXXV, but only upon those in which observations were taken at one-minute, or at most, two-minute intervals. In general, therefore,

a) Amoeba may move at a uniform rate of locomotion at any temperature.

b) Such a rate of locomotion is not long sustained, not longer than from 5 to 7 minutes in exceptional cases, but ordinarily, not longer than from 2 to 3 minutes.

c) Moderate or low rates of movement are more likely to be sustained uniformly for several minutes than are high rates.

d) Amoeba moves at a uniform rate more frequently at lower than at higher temperatures. In no case was a uniform rate sustained for longer than 3 minutes in temperatures higher than 19.5 degrees. Some individuals moved at a uniform rate for 2 minutes in temperatures as high as 26 degrees.



b) Locomotion at Suddenly Accelerated or Suddenly Retarded Rates (Fig.9).

A further analysis of the behavior of Individual XII will show that Amoeba may move at rates that change with very great rapidity. A change of 4 or more mm. per minute in its rate occurred on 5 occasions during one-minute intervals, while a retardation of 4 or more mm. per minute occurred on 6 occasions during one-minute intervals. The greatest acceleration occurred between observations 67 and 68, a change from 3 to 7.5 mm. per minute, a change, therefore, in rate of 4.5 mm. (Fig. 9,a). The greatest retardation occurred between observations 20 and 21, a change from 9 to 4 mm. per minute; a change, therefore, in rate of 5 mm. (Fig. 9,b). Within two successive minutes, an amoeba may more than double its rate, or it may reduce it by more than one half.

Selecting at random other instances of the same phenomenon, Individual XIX changed from a rate of 3 mm. to one of 9 mm. (Fig. 9,c), and again from 6.5 mm. to 2 mm. (Fig. 9,d) in two successive minutes. Again, in two successive minutes, Individual XV changed from a rate of 6 to one of 1.6 mm. and from 1.6 to 6.5 mm. (Fig. 9,e). Individual XVIII changed from 9 to 5. mm. (Fig. 9,f), and from 7 to 2 mm. (Fig. 9,g); Individual XXI from 3.5 to 10 (Fig. 9,h) and from 9 to 2.5 mm. (Fig. 9,i). The greatest sudden acceleration that was observed occurs in the records for Individual XXXI, a change from 3.5 to 17.5 mm. (Fig. 9,j); while the greatest sudden retardation is found in the records for Individual LIII, a change from 13.5 to 4.25 mm. (Fig. 9,k).

We may conclude, therefore,

1) The rate of locomotion of Amoeba may change very rapidly.

2) The rate of locomotion may increase five-fold, or decrease by more than one third, in two successive minutes.

3) Such extreme changes are comparatively rare, however, while a doubled rate, or a rate reduced by one half occurs with comparative frequency.

4) Smaller changes in rate during two successive minutes must be considered a feature of the normal behavior of the amoeba.

Fig. 16.

c) Locomotion at Gradually Accelerated or Gradually Retarded Rates (Fig.10).

Another rather frequent method of changing the rate of locomotion is found in Amoeba. The rate may be gradually accelerated or gradually retarded. It is highly probable that in the animal itself this process takes place continuously, that is, as a uniformly accelerated motion, but as it is manifested to an observer who measures the rate of locomotion from minute to minute, the process seems discontinuous. When plotted, such a mode of locomotion appears as a "stair-case" graph. The "stair-case" may be upward, if the acceleration only is gradual; or downward, if the retardation only is gradual; or double, if both the acceleration and the retardation are gradual.

Individual XII(Fig. 10,a) furnishes an illustration of a single, upward "stair-case". From 11:11 to 11:16 o'clock, the animal was moving at a rate of 1.5 mm. per minute. During the next five minutes, the rate increased to 1.8 mm. During the ensuing 2 minutes the amoeba moved at a rate of 3 mm. per minute, then at rates of 3.5, 3.8 and 5 mm. per minute, each sustained for 2 minutes. From 11:29 to 11:30 it moved at a rate of 9 mm. per minute. It took 17 minutes, therefore, to change the rate of locomotion from 1.5 to 9 mm. per minute, and during that time interval there was continuous acceleration, in the course of which 6 different rates were observed and measured. The essential point to be noted in this mode of behavior is the gradual upward or downward change of rate, <u>without an intervening retardation</u> in the case of a gradual acceleration, or an <u>intervening acceleration</u> in the case of retardation.

Other individuals manifested this mode of behavior rather frequently. Individual I, (Fig. 10,b) took 15 minutes to change from a rate of .2 to

one of 4 mm. per minute with 4 intervening rates, and again during 8 minutes, it retarded its rate from 4 to 1.7 mm. per minute with 3 intervening rates. Individual XXXVIII (Fig. 10,c) took 12 minutes to change from a rate of 1.5 to one of 4 mm. with 5 intervening, gradually accelerating rates. Similarly, Individual XXVI (Fig. 10,d) changed its rate from 3 to .3 mm. per minute, with 5 intervening, gradually retarding rates. Individual XXXVIII (Fig. 10,c), moreover, furnished an excellent illustration of a double "stair-case". Instances of this phenomenon might be multiplied but they may easily be found from a brief inspection of the tables and graphs.

This mode of behavior, moreover, is not characteristic of any particular temperature. Individual I manifested the behavior just described at 9 degrees; Individual XXXVIII at 9.5 degrees; Individual XVII, at 15 degrees; Individual XXVI, at 19 degrees; Individual XI, at 23 degrees. No clear cases of this phenomenon, however, are found at the higher degrees, sc. at those above 23 degrees.

Amoeba may, therefore,

(1) Gradually accelerate or retard its rate, the change from one rate to another taking place very slowly.

(2) As long an interval as 19 minutes may be necessary to effect a change of only 1.9 mm. in acceleration, or of only 2.7 mm. in retardation.

(3) This mode of changing its rate of locomotion may take place at any temperature but it is much more frequent at lower and medium than at higher temperatures.

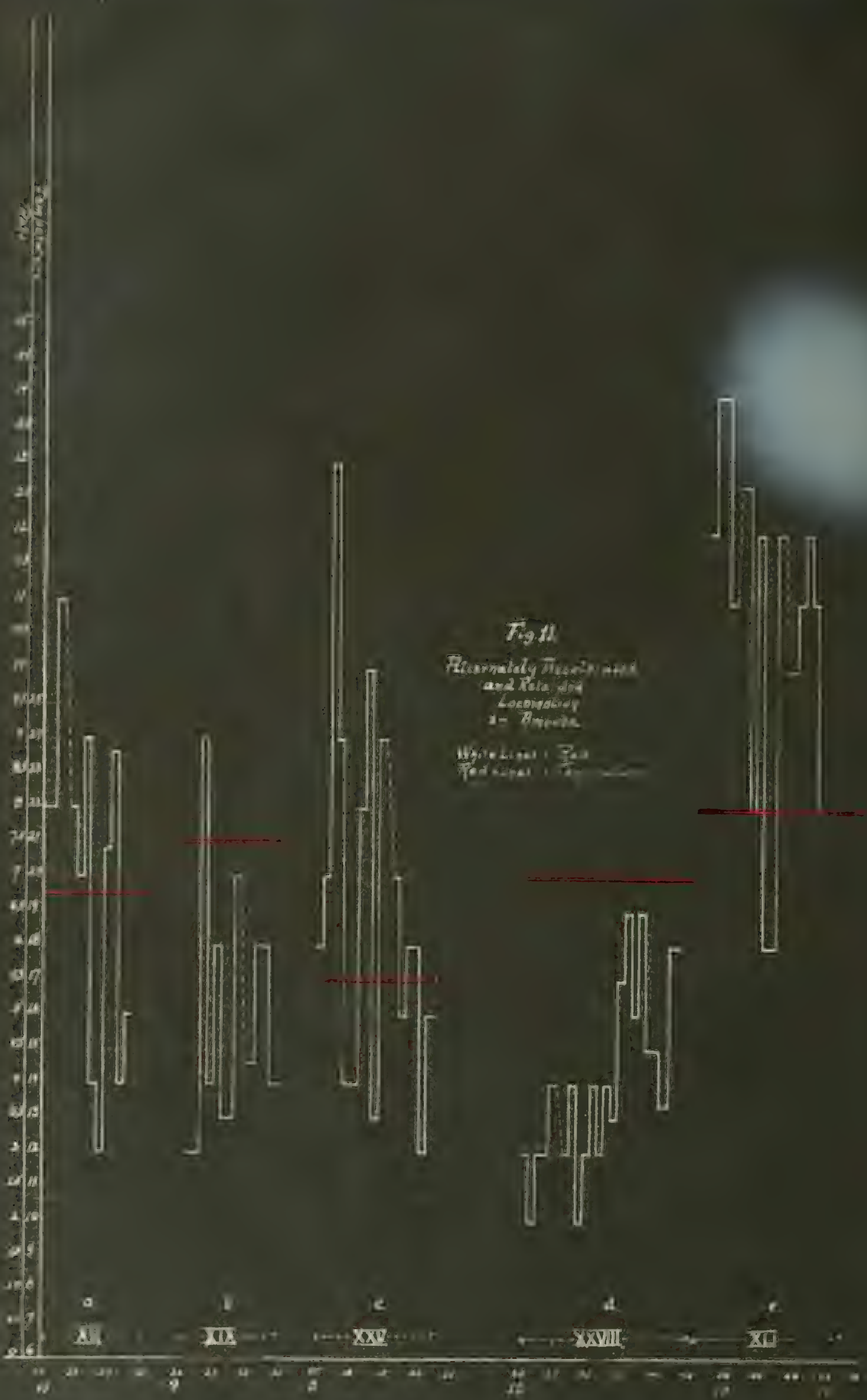


Fig. 11
Locomotion
a
b
c
d
e
XIX
XXV
XXVIII
XL

d) Locomotion at Alternately Accelerated and Retarded Rates (Fig. 11).

Finally, Amoeba may move at rates that are alternately accelerated and retarded. Individual XII (Fig. 11,a) again manifests this activity, though not in as striking a degree as some of the other individuals. During 2 minutes from 9:20 to 9:22 it was moving at a rate of 8 mm. per minute; then its speed was accelerated to a rate of 11 mm.; then it was retarded to 8 mm. and to 7 mm.; then again accelerated to 9 mm.; then again retarded to 4 mm. and to 3 mm.; then again accelerated to 7.4 mm. and to 8.8 mm.; then again retarded to 4 mm. and finally again accelerated to 5 mm. per minute.

Individual XXVIII (Fig. 11,d) shows an even more regular and striking alternation of these periods of acceleration and retardation. At 12:20 o'clock it was moving at a rate of 3 mm. per minute. Then, in successive minutes, it moved at rates of 2, 3, 4, 3, 4, 2, 3, 4, 3, 4, 3.5, 5.5, 6.5, 5, 6.5, 4.5, 3.7, 6 mm. per minute. The alternate periods of increasing and decreasing speed in this series are obvious. Individuals, XIX (Fig. 11,b), XXV (Fig. 11,c) and XLI (Fig. 11,e) may be further cited as manifesting this peculiarity of behavior rather strikingly.

This mode of behavior, like those previously described, also seems to be independent of temperature. Still, it occurs more frequently at higher than at lower temperatures, though our data do not indicate that it occurs more frequently at higher than at medium temperatures.

There are numerous detailed features of this alternation of accelerating and retarding phases, which it would be interesting to illustrate in detail from the individuals studied. It will have to suffice for the present, however, to make the following preliminary statements

which may be verified by a comparative study of the graphs and tables. A more detailed study will be made in the section dealing with the rhythm of locomotion.

1) Ameba may move at alternately increasing and decreasing rates.

2) Such a period of alternation may occur at any temperature, though it occurs more frequently at higher than at lower temperatures.

3) The duration of such a period of alternation is variable. It may be as brief as 2 or as prolonged as 20 minutes.

4) In periods of rather long duration, there may be occasional aberrations from the regular sequence, and an acceleration or a retardation of 2 or 3 minutes may occur in a series in which the alternations take place regularly every minute.

5) The duration of such a period of alternations is probably longer at higher than at lower temperatures.

6) Ordinarily, such a period occurs when Ameba is moving rather rapidly, though it may occur even when it is moving at slow rates.

7) In such a period of alternating accelerations and retardations, the extent of acceleration is apparently not dependent on the preceding retardation, nor is the extent of retardation dependent on the preceding acceleration.

8) In a series, if the various accelerations show a progressively increasing value, the intervening retardations may show decreasing values, though not necessarily so.

9) In a series, if the various accelerations show progressively decreasing values, the intervening retardations may show increasing values, though not necessarily so.

C. THE RHYTHMIC CHARACTER OF LOCOMOTION

a) An Illustration

Locomotion by alternately accelerated and retarded rates, which we have just considered, leads us directly to discuss the third feature that is suggested by a study of the performance graphs, the rhythmic character of locomotion. This feature might be illustrated by a study of Individual XII, but Individual XXVIII affords a more definitely clear case. A part of the performance graph of this individual has been reproduced in Fig. 10,d, and it is this graph which we shall subject to further study.

The first observation made upon this individual showed that it was moving at a rate of 3 mm. per minute. There was no way of finding out, of course, whether this rate was an accelerating or a retarding rate, and hence for the purpose of the present discussion, we may disregard it. The succeeding observations on this individual may be grouped in a series of periods, somewhat as follows:

Period	1,	Retardation,	1	minute;	Acceleration,	3	minutes.
"	2	"	1	"	"	1	"
"	3	"	1	"	"	2	"
"	4	"	1	"	"	1	"
"	5	"	1	"	"	2	"
"	6	"	1	"	"	1	"
"	7	"	3.5	"	"	1.5	"

The periodicity here is unmistakable. Not only are there alternate accelerations and retardations, but the alternate accelerations, those namely of Periods 1, 3, 5, 7, are slower than those of the intervening accelerations, those of Periods 2, 4, 6.

Fig. 18
Rhythm of Locomotion
Short Period Rhythm
(Index XXVIII)

b) The Ratio of Rates

(1) The Ratio of Rates for One Individual.

In this particular case there is, moreover, an almost ideally perfect quantitative relationship between the rates assumed during the total time of observation. During the retardation of the first period, the animal was moving at a rate of 2 mm. per minute. During the acceleration of this period, the animal moved at a rate of 3 mm. per minute for 2 minutes, and at a rate of 4 mm. for 1 minute. Hence, during this accelerating phase, which lasted 3 minutes, the amoeba moved a total distance of 10 mm. and, therefore, at a rate of 3.33 mm. per minute. If we now divide the rate maintained during the accelerating phase by that maintained during the retarding phase, the quotient will give us a measure of the number of times by which the accelerating rate exceeded the retarding rate. We may call this value the "Ratio of Rates", and its mathematical value will be indicated by the expression, R_{ac} / R_{rt} throughout the present discussion. During the first period of the locomotion of Individual XXVIII, which we have been considering, the value of this ratio is 1.66, since the average accelerating rate was 3.33, the average retarding rate was 2.

For the second period the value of this ratio is 1.33; for the third, 1.75; for the fourth, 1.35; for the fifth, 1.71; for the sixth, 1.3. and for the seventh, 1.46. Table IX summarizes these facts, and shows, moreover, how these values were derived. From this table, especially if it is studied in connection with the graphs, Fig. 8,d, and the enlarged graph (Fig. 12), the following points will become clear:

a) There was a very evident rhythm in the locomotion of this individual.

b) This rhythm expressed itself not merely in an alternation of accelerations and retardations but also in an alternation of periods of greater with those of less acceleration (Compare the Ratio of Rates for

T A B L E IX

Rhythm in the Locomotion of Individual [illegible]
During Twenty Minutes
(See Graph, Fig. 11, d)

D = Distance traversed by animal during stated period
T = Time interval
R_{ac} = Rate during acceleration
R_{rt} = Rate during retardation

Period	Retarding Phase			Accelerating Phase			R_{ac} / R_{rt}
	D	T	R_{rt}	D	T	R_{ac}	
1	2	1	2	6 4 10	2 1 3	3.33	1.66
2	3	1	3	4	1	4	1.33
3	2	1	2	3 4 7	1 1 2	3.5	1.75
4	3	1	3	4	1	4	1.33
5	3.5	1	3.5	5.5 6.5 12.0	1 1 2	6	1.71
6	5	1	5	6.5	1	6.5	1.30
7	9.0 5.5 14.5	2 1.5 3.5	4.1	9	1.5	6	1.46

Periods 1, 3, 5, 7 on the one hand with those of Periods 2, 4, 6 on the other).

c) The value of the ratio R_{ac} / R_{rt} was remarkably constant in alternate periods.

Such striking regularity in a complex rhythm is rare in the whole mass of data at our disposal. There are, however, a few instances which are just as noteworthy as is the case of Individual XXVIII. Individual XLVII, for example, exhibits this same phenomenon. A possible reason why it is not easy to discover such instances more frequently is this, that the difficulties incident upon our method of observation, make it all but impossible to follow a given animal uninterruptedly for a very long time. Whenever one of the record sheets upon which the drawings were made, had to be changed, this could not well be done without the loss of half a minute's time, and during such a time interval, brief as it is, an entire phase, either accelerating or retarding, might be lost.

There can be no question, then, concerning the rhythmic character of locomotion, nor, in certain instances, concerning the accurately quantitative feature of this rhythm. As might be expected, however, this quantitative feature may be subject to very wide variations. To show the general character of these variations, the value of the Ratio of Rates has been worked out for the other individuals, whose performance graphs are reproduced in Fig. 11 , i.e. for Individuals XII, XIX, XXV, XLI. These values are found in Table X. It will be noted that Individual XXV shows the same alternation of greater and smaller values for the Ratio of Rates which were discovered in Individual XXVIII, the values for the 1st

T A B L E X

The Value of R_{ac} / R_{rt}

For the Periodicity of Locomotion

(Performance Graphs for all of these Amoebae are given in Fig. 11)

Individual	Designation in Figure	Period	R_{ac} / R_{rt}
XII	a	1	1.2
		2	2.6
		3	2.0
XIX	b	1	2.25
		2	1.70
		3	1.60
		4	1.50
XXV	c	1	1.52
		2	2.60
		3	1.50
		4	2.00
XLI	e	1	1.27
		2	1.60
		3	2.00
		4	1.20
		5	1.20

and 3rd periods being practically equal and small, those for the 2nd and 4th periods being comparatively large. For Individual XLI, the data are insufficient to enable one to discuss the quantitative character of the rhythm. Individual XIX moved in such a way as to gradually reduce the value of the Ratio of Rates. Individual XLI, on the other hand, moved in such a way, as to increase the value of the Ratio of Rates, and then to make the value of this ratio constant. Such cases will have to be discussed at greater length when we speak of the long-time rhythm of locomotion.

(2) The Ratio of Rates for Several Individuals at the Same Temperature

In discussing the rhythm of locomotion in Amoeba, we have considered, thus far, the Ratio of Rates for the successive accelerations and retardations in the locomotion of one individual. Another rather striking feature of this rhythm is the comparative constancy of the value of this Ratio, for the average rates during accelerating or retarding phases for different individuals at the same temperature. If we add the distance traversed by a given individual during all the periods of acceleration observed at a given temperature, and divide this distance by the total duration of the accelerating phases, we shall get the average rate maintained by the animal during the accelerating phase. Similarly, if we add the distance traversed by the same individual during the periods of retardation, and divide this distance by the total duration of the retarding phases, we shall get the average rate maintained during the retarding phases. If we now get the Ratio of Rates, by dividing the average rate during the accelerating phases by the average rate during retarding phases, we shall find by how many times the average accelerating rate exceeded the average retarding rate.

Table XI will illustrate the treatment of our data for the present purpose for Individual XXIV. The table is divided vertically into two halves, one for the accelerating phases, the other for the retarding phases. In the first column in each half is given the distance traversed by the animal during a given time interval, in the one case during the accelerating, in the other during the retarding phase; in the second column is given the time interval during which that distance was traversed. Thus, in the first line, under the "Accelerating Phase" will be found the reading 22 in the distance column, and 2 minutes in the time interval column, which means that during the first accelerating phase, this individual

TABLE XI

The Ratio of Average Rates
of the
Locomotor Rhythm
of
Individual XXIV
At 20 Degrees

Period	Accelerating Phase: Distance Mm.	Accelerating Phase: Time Interval Min.	Retarding Phase: Distance Mm.	Retarding Phase: Time Interval Min.
1	22	2	8	1
			5	1
2	14	1	8	1
			12	1.5
3	8	1	14	2
	14	1	3	1
			2	1
4			13	1
			10	1
			8	1
			7	1
	22	2	6	1
5	12	1	8	1
	14	1	6	1
6			9	1
	16	1	6	1
7			15	1
	13	1	12	1
	135	11	154	19.5

Average Rate, during Accelerating Phase, R_{ac} = 12.3 mm

Average Rate, during Retarding Phase, R_{rt} = 8.

$$\frac{R_{ac}}{R_{rt}} = \frac{12.3}{8.0} = 1.5$$

moved 22 mm. in 2 minutes. Similarly, the first line under the Retarding Phase is to be understood thus, that this individual moved 8 mm. during 1 minute. If now, we add all the values given in the distance column under "Accelerating Phase" we shall get the total distance traversed by the animal during all the accelerating phases of its rhythm. If this value is divided by the sum of the values of the time intervals, we shall get the average rate of this individual during all its accelerating phases. The total distance traversed by Individual XXIV was actually 135 mm., during 11 minutes, and, therefore, its average rate during the accelerating phases was 12.3 mm. per minute. Treating the data under the "Retarding Phase" in the same way, we find that the average rate during the retarding phases was 8 mm. per minute. Hence, the value of R_{ac}/R_{rt} in this case is 12.3 divided by 8, which gives 1.5 as the value of our Ratio of Average Rates. This means that on the average the animal during the accelerating phases moved 1.5 times as fast as it did during the retarding phases.

Now if we subject the data for a number of individuals, all of which were observed at 20 degrees, to the same sort of analysis, it will become apparent that the value for the Ratio of Average Rates is strikingly constant. The results of such a study are embodied in Table XII. The table is constructed very much like Table XI for which the explanatory details were given on page 73. It will be noted that even though the value of the accelerating rate (R_{ac}) varies between such wide limits as 3.10 mm. per minute for Individual XVI and 12.3 mm. per minute for Individual XXIV, and the value of the retarding rate varies between 1.8 mm. per minute and 8 mm. per minute for the same two individuals, respectively, the Ratio of Average Rates, for all of these individuals lies between 1. and 2.5. The value of the Ratio of Average Rates for all of these individuals is 1.5.

T A B L E XII

The Ratio of Average Rates of the Locomotor Rhythm of Amoebae at 20 Degrees

D = Distance traversed by animal during stated period
T = Time interval
R_{ac} = Rate during acceleration
R_{rt} = Rate during retardation

Individual	Accelerating Phase			Retarding Phase			R_{ac} / R_{rt}
	D	T	R_{ac}	D	T	R_{rt}	
XIII	[illegible]	26	3.45	57.1	31	1.84	1.9
XVI	50.5	16	3.10	47.0	26.5	1.80	1.7
XVII	122.6	15.5	7.90	107.5	19.5	5.50	[illegible]
XVIII	127.5	33.5	3.80	52.0	34.0	[illegible]	2.5
[illegible]	58.0	13.5	3.60	40.0	17.5	2.30	1.6
XIX	[illegible]	22.5	4.30	41.5	17.5	2.40	1.8
[illegible]	94.3	[illegible]	3.40	36.2	24.5	1.50	2.3
[illegible]	94.0	15.5	6.10	54.0	13.0	4.10	1.5
[illegible]	135.0	11.0	12.3	154.0	19.0	8.0	1.5
XXX	65.5	8.0	8.20	82.0	16.0	5.10	1.6
XXXI	56.0	11.0	5.10	45.5	17.0	2.70	1.9
XXXIII	75.5	17.5	4.30	51.0	12.0	[illegible]	1.0
XXXVI	112.0	13.0	8.60	120.0	17.0	7.00	1.20
XL	66.5	9.0	[illegible]	65.0	12.0	5.40	1.40
[illegible]	[illegible]	9.0	5.20	40.0	15.0	2.70	1.90
[illegible]	[illegible]	13.5	5.00	29.0	8.0	3.60	1.4
	1376.35	[illegible]	[illegible]	1050.3	317.5	[illegible]	1.5

The only basis for the selection of the individuals for which the results were to be included in this table, was the length of time during which they were observed. Those only were chosen which had been observed in a locomotor condition at 20 degrees for 30 minutes or more, so that there might be some assurance that the characteristic features of the activity had actually been found.

(3) The Ratio of Rates for Several Individuals at Different Temperatures

Finally, if we compare the value of the Ratio of Rates for several individuals at different temperatures another feature will become apparent. Unfortunately, however, our data are not adequate for forming a definite conclusion on this matter. Still, if we select a number of individuals at different temperatures, choosing only those that have been observed for quite a long time, and then treat their records as the data for 20 degrees were treated, we shall notice a gradual diminution of the value of the Ratio of Rates as the temperature rises. These facts are illustrated in Table XIII. Only the final summations are given in this table to avoid needless complication of the table. To show how much evidential value is to be attached to the results for the various temperatures, the number of individuals from the records of whose performance the data are derived, is given in the first column. The second column gives the temperatures at which the observations were made. The remaining part of the table is compiled as was described previously on page [illegible] for Table IX.

It is to be regretted that the number of individuals for which the data are presented are so few for some of the temperatures. It is thought probable, however, that the general trend of the data would not be changed even if the experimental facts were more numerous. No effort was hitherto made to work over the data for the intermediate temperatures.

T A B L E XXII

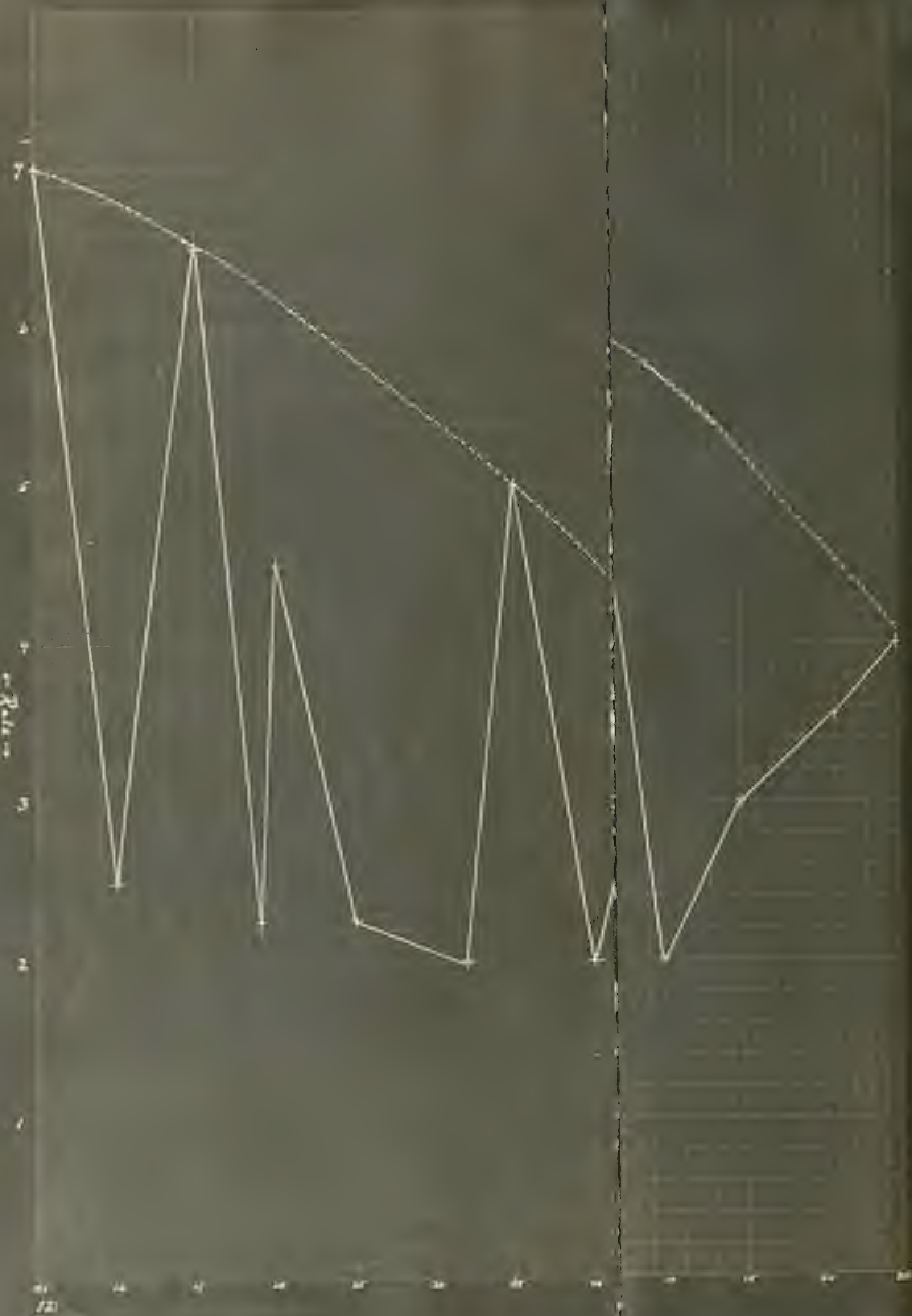
The Ratio of Average Rates of the Locomotor Rhythm of Amoebae at Various Temperatures

D = Distance traversed by animal during stated period
T = Time interval
R_{ac} = Rate during acceleration
R_{rt} = Rate during retardation

No. of Individual observed at a given temperature	Temp. C	Accelerating Phase			Retarding Phase			R_{ac} / R_{rt}
		D	T	R_{ac}	D	T	R_{rt}	
4	15	178	56.75	3.13	172.5	[illegible]	1.72	[illegible]
5	18	638.5	83.00	7.70	424.5	87.50	4.90	1.57
16	20	1376.35	276.00	5.18	1050.3	317.50	3.40	1.50
4	25	652.0	64.53	10.10	576.5	[illegible]	[illegible]	[illegible]

It will be noted that at 15 degrees the value of the Ratio of Rates is 1.9, at 18, it is 1.57, at 20, it is 1.5 and at 25 degrees, it is 1.26. The progressive downward value is quite evident. We shall come back to a discussion of this phenomenon after we have treated the following section, -- the long-time period rhythm in the locomotion of Amoeba.

FOLD OUT



c. The Long-Period Rhythm

In addition to the periodicity manifested by an alternation of accelerations and retardations, there became evident in some of the amoebae used in this study, another long-period periodicity, the full meaning of which and the laws of which will need further investigation. This long-period rhythm becomes manifest, only, when an individual is studied at the same temperature for a prolonged time interval. In this matter, as in many others connected with amoeboid movement, it is most important to note Schaeffer's warning, that we have not explained amoeboid movement when we have explained amoeboid behavior at any particular cross-section of time. He says, "It has been tacitly assumed that if one could explain amoeboid movement at any particular cross-section in time, one understood the whole process of amoeboid movement no matter how long it continued.....It was not assumed that time was an element in the practical sense in the explanation of locomotion." Schaeffer, ('20, p. 109). Individual XVIII will serve as an illustration. To facilitate description, the performance graph for this individual has been re-drawn on an enlarged scale, some of the smaller fluctuations of the rate were omitted, and the rates for every fifth minute only, (in one case for a four-minute interval) were plotted. (Fig. 12,A).

The alternations of accelerating and retarding rates become evident at once. But just as evident in the gradual decrease of the accelerating rates from 12:05 to 1:00, its gradual increase to 1:25, then again its decrease until 1:45 o'clock, its increase to 2:05 o'clock, and finally, probably, its decrease beyond this time. It is clear that a very long time period of continued observation of the same individual at constant temperature is required to reveal so complex a form of behavior.

As our data for the understanding of this phenomenon are so meagre, little more need be said about it, but still certain features which we have

alluded to above may be mentioned in passing, as it is possible that this long-period rhythm may help us in understanding some of the features of the short-period rhythm.

It will be noted first of all, that the performance graph of an amoeba, even for a comparatively short time interval, will look quite differently, depending on whether it represents the condition of the animal when it is in the downward or the upward phase of the long-period rhythm. This MAY explain the decided difference in the appearance of the graphs for Individuals, XII, XIX, XVI and XVII, all at 20 degrees for example. A brief reference to the appendix where these graphs may be found, will make our meaning clear. In the case of Individual XII, there is at first an upward tendency of the line connecting the various maxima, then a downward tendency, and again an upward tendency. In the case of Individual XIX, there is clearly a downward tendency of the line connecting the maxima. The graph for Individual XVI, too, shows this same downward tendency while the character of the graph for Individual XVII seems to indicate that locomotion of this amoeba was studied while the animal was at the crest of a long-period rhythm.

Thus far, we have spoken of the curve connecting the maxima of the rates of locomotion. Other interesting relationships would probably be revealed, if our data were ample enough to warrant an extensive discussion of the line connecting the minima. A few considerations by way of suggestion, rather than of definite statement, may not be out of place.

If the curve of minima runs parallel to the curve of maxima, the curves must be interpreted as meaning that for every increase or decrease in the accelerations, there is a corresponding increase or decrease in the retardations. Under such conditions, clearly, we should expect the Ratio of Rates (defined above, p.6[illegible]) to remain constant. Again, if the curve of minima converges towards the curve of maxima, the meaning is probably this, that while the acceleration is increasing or decreasing, the retardations and accelerations are varying in an opposite sense. In such a case, we should expect the Ratio of Rates gradually to decrease in value. Individual XIX affords an illustration of this. Reference to Table X will help us to recall that the Ratio of Rates for this individual decreased during four successive periods from 2.25 in the first period to 1.50 in the fourth. Thirdly, if the curve of minima diverges from the curve of maxima, we should expect the Ratio of Rates gradually to increase. Individual XLI illustrates the point. Further reference to Table X will show that for the first three periods the Ratio of Rates gradually increased, from 1.37 to 2.00 and then remained constant.

Lastly, since in all these three cases the curve of minima is certain to run parallel to the curve of maxima, for some time, near its central region, we should expect to find in each individual a number of alternate accelerations and retardations for which the Ratio of Rates is fairly constant. This, in fact, occurs frequently, and the instance of Individual XXVIII, (Table IX and Fig. 11) furnishes an excellent illustration.

3. A DISCUSSION OF CERTAIN FEATURES OF LOCOMOTION of AMOEBA, AT CONSTANT TEMPERATURE.

We are now in a position to summarize all that has been said about the locomotion of Amoeba at constant temperature. It is not our purpose in this place to study the bearing of our data on a theory of the mechanics of amoeboid movement. Our purpose is rather to suggest a relation which may possibly exist between the features of locomotion which we have been describing and the physiological condition of the amoeba during its locomotor activity.

We have emphasized the following features of locomotion:

(1) Locomotion in Amoeba is rhythmical.

(2) This rhythm expresses itself in a variation of the rate of locomotion.

(3) The rhythm is probably two-fold, a long-period rhythm and a short-period rhythm.

(4) In each of these rhythms, there is an accelerating and a retarding phase.

(5) In the short-period rhythm -- possibly also in the long-period rhythm -- the accelerating and retarding phases are variable.
  a) in intensity,
  b) in duration.

(6) The relation between the two phases is expressible by a ratio, the value of which is approximately constant for a given temperature.

(7) At different temperature, the value of this ratio is variable, decreasing with rising and increasing with falling temperature.

(8) At any given instant, the rhythmical character of locomotion may not be evident by reason of the various modes in which Amoeba may change its rate of locomotion. For Amoeba may change its rate of locomotion,
  a) after having moved at a uniform rate for a considerable interval of time.
  b) by suddenly accelerating or suddenly retarding its rate.
  c) by gradually accelerating or gradually retarding its rate.
  d) by alternately accelerating and retarding its rate.

(9) After a prolonged period of observation, however, the rhythmical character of locomotion becomes evident in one of two ways, and sometimes in both:
  a) by the constancy of the Ratio of Average Rates.
  b) by the undulation of the curve of maximal rates.

These details in the locomotor rhythm are of so striking a character that they invite an effort at interpretation.

Without committing ourselves to anyone of the numerous theories of amoeboid movement, everyone who has studied Amoeba must be familiar with the "eruptions" of granules for some "dynamic center", which occur during locomotion. These eruptions occur at more or less regular intervals, and are followed by shorter or longer periods of gradually retarding flow. These alternations of active and refractory periods produce the "short-period" rhythm.

The special form of rhythmic activity which we are here discussing is the rhythm of rate of locomotion. There are probably other forms of rhythmic activity which are associated with locomotion. Schaeffer ('20) for example, without speaking of rhythmic activity, has pointed out a dextero-sinistrous, sinuous movement in the locomotion of A. bigemma, as well as in other forms. It is probable, moreover, that there is in Amoeba a time rhythm, which depends upon the relative durations of the active and refractory periods, or, as we have called them, the accelerating and retarding phases. Gibbs and Dellinger ('08, p. 241) have pointed out that "The Amoeba proteus in common with higher animals has distinct periods of work and rest, depending for degree and duration upon the nature and abundance of food upon which the animal is habitually feeding." In all likelihood, all of these various forms of periodic activity are, if not expressions of identically the same physiological state, still, of closely related ones. Even from our own data upon this matter, it would seem high probable that there is a close relation between the time-rhythm and the rate-rhythm, and suggestions are not wanting, that both of these may be coincident with Schaeffer's directional rhythm.

Without leaving the sure foothold of observational and experimental fact, however, it may be stated definitely that there are alternations of accelerated and retarded rates of locomotion. The accelerated phases of locomotion occur synchronously with the eruption, and the retarded phases, with the refractory periods. We may, therefore, conceive of the eruption as the release of accumulated energy; of the refractive phase as a period in which two things are happening,

a) the utilization or dissipation of the released energy,

b) the storage in the "dynamic center" of materials, perhaps, which will furnish the driving force for the next eruption. In other words, the rhythm may be conceived, as it has been explained in so many rhythmic biological processes, as the expression of <u>reversible metabolism</u> of energy. In the eruptive phase, potential is converted into kinetic energy; in the refractive phase, potential energy is being "accumulated" preparatory to the next period of release.

The eruptions may vary (1) in frequency, (2) in intensity. The frequency of the eruptions conditions the "closeness" of the rhythm, the number of rhythmic waves, namely that are packed into a given time interval. Now, this frequency can be altered in only one fundamental way, that is, by a change in the time interval between the various eruptions. But the relation in duration between the eruptive and the refractive phases may be altered in a great many ways:

a) the eruptive phase may be long and the refractive phase short;

b) the eruptive phase may be short and the refractive phase, long;

c) an eruption may occur at the end of the dissipative phase, or after the dissipative phase has barely begun, or at any intervening point of time between these two.

The eruptions may vary, moreover, in intensity. The intensity of the eruption will determine the amplitude of the eruptive phase, and will

of rate.

The refractive period, too, may vary, at least, in time. The observational basis for this statement is the fact that the rate of locomotion may be retarded very suddenly or gradually. Since two processes, as we have said, are taking place in the organism during this period, each of these again, may have its own velocity. The ultimate resultant of these processes, however, will finally be expressed in the magnitude and rate of the succeeding eruption.

All of this might well be developed at much greater length. There is ample scope for speculation, and the whole subject of wave motion might supply endless suggestive analogies. Actual instances of the rate of locomotion of Amoeba might, without laboring the point, be interpreted as reinforcement or interference of waves of the rhythm. It will suffice to point out, however, that with these various factors, each of which may vary in frequency and in intensity, almost all the qualitative and quantitative variations of the locomotor rates of Amoeba, which we have described, may be adequately defined. It will also be evident that the locomotor behavior must not be conceived as a comparatively simple manifestation of physiological conditions. The interplay of the environment on the one hand, and the complex physiological factors on the other, must necessarily be of so complicated a character that it is definable by no simple formula.

It remains to point out the possible applications of all this to some of the outstanding modes of locomotor behavior which we have described.

(1) We have seen that Amoeba may move at a uniform rate for a long time interval. We may well interpret this as due to a series of very frequent eruptions of small amplitude, so small, that to be detected, they would have to be measured under a higher magnification and at shorter time intervals than was done in this investigation.

(2) Amoeba may move at a suddenly, greatly accelerated rate. The acceleration, in this case, is probably due to a sudden, almost instantaneous

eruption of great magnitude.

(3) Amoeba may move at a gradually accelerated rate. Such an acceleration is probably due to a slow eruption of greater or smaller magnitude. In this form of motion, as we have seen, the eruption may be so slow that several, different measureable rates may be found in as many as six successive minutes, during which the rate of the eruption constantly increases, giving us, what we have designated as a stair-case mode of motion.

(4) Amoeba may move at suddenly or gradually retarded rates, these again varying in the magnitude of the variation. Such a retardation may be interpreted as due to varying lengths in the refractory periods, and to different intensities of the processes that take place during that period.

(5) The constancy of the Ratio of Rates, at a given temperature, will also, probably, be found to be explainable on the basis of rhythm.

Before proceeding with the discussion of this statement, a note must be inserted here. In this discussion of the rhythm, of the rate of locomotion, and later on, in the discussion of the possible meaning of variations in the value of the temperature coefficient, we shall take occasion to refer repeatedly to Woodruff's ('11, '11a, '17) papers on the reproductive rhythm in Paramoecium. The comparison between our short-period and long-period rhythm on the one hand and Woodruff's "rhythm and cycle" on the other would seem to demand some vindication. Other workers in the protozoa have found rhythms in the reproductive activity of the lower forms. But as Woodruff was among the first to point out the existence of the rhythm, and as his work was the point of departure for other investigators in this field, his results have been chosen for comparison with the phenomena now being discussed. Woodruff's "rhythm and cycle" were of much longer duration than the short-period and long-period rhythms of which

we are speaking. In our comparison, therefore, we are merely comparing certain features of rhythmic activity, which Woodruff has pointed out, with those that seem discoverable in the present work, and are in no way implying a belief in the identity or even similarity in the underlying physiological processes.

Now, Woodruff ('11) in the paper in which he established the existence of a rhythm in the reproductive activity of Paramoecium, says the following: "It should also be pointed out that the total number of divisions during a prolonged period of time is comparatively constant. For example, the number of generations attained by a culture during 1909 was 613, and during 1910 was 612. Of course, this very exact coincidence is an 'accident' but taken with a considerable amount of data along the same line, it quite definitely points to the fact that the organism has the potential for about a certain number of bipartitions during a long period of time and this number is approximately attained irrespective of the minor fluctuations in the rate, due to external or internal causes." (pg. 355-6)

If this may be said concerning a process like reproductions, which, presumably, is so much more complicated than the rhythm of the rate of motion which we are here discussing, the constancy of the Ratio of Rates does not seem so very surprising. We may, therefore, conclude with some degree of probability that -- to parallel Woorruff's statement -- Amoeba has a certain potency for a given amount of locomotion during a long period of time, and this amount is practically constant, -- unless, as happens in our case -- external factors, temperature, for instance, so influence that potency as to increase or decrease it. What the concrete, objective meaning of this potency is, cannot be said with definiteness. That it is associated in the present case with certain limitations set to the elasticity and exstensibility of protoplasm by the

temperature conditions, seems all but certain, but this is by no means to assert that this potency is not dependent upon regulative internal factors.

(6) In addition to the rather remarkable constancy of the rates at constant temperature, we have also seen that the value of this ratio changes at different temperature, but that this change is comparatively slight. Again, we appeal to Woodruff for a parallel case. (Woodruff, '11, pg. [illegible]) "A study of the curve of the division rate at the two temperatures shows that temperature, as is well known, markedly influences the rate, but it also shows that the rhythms persist -- the reproductive activity being, as it were, pitched at a higher scale, but its character is in no wise altered." Perhaps, the changed value of the ratio of rates is the quantitative expression of "change of pitch". As we have no data to present upon the meaning of the decrease in the value of the ratio of rates with increasing temperatures, this suggestion is not of much value, except as a point of departure for further experimentation.

(7) Lastly, a word might be said about the long-period rhythm, -- Woodruff's cycles. It has been suggested that cycles in the life-periods of protozoa have a definite correlation with conjugation. In the case of paramecium, the interesting suggestion has been made that at the apices of the reproductive rates, conjugation is much more frequent. In this respect, therefore, the long-period rhythms in the present investigation have no relation whatever to Woodruff's cycles. But in another sense, perhaps, there is some analogy. All that we should want to point out by the analogy is the existence of periodicity not merely in physiological processes, but also in the successive maxima of these processes. In another respect, the analogy proves to be correct.

Woodruff has found that when environment of his cultures is changed, "cycles do NOT occur, but rhythms persist." ('11, pp. 557). By reason of this statement, and other similar ones, some doubt has been cast upon the existence of "cycles" in the reproductive activity of Paramecium. In the present investigation, however, it can be seen from a comparison of the performance graphs, that while short-period and long-period rhythms are clearly evident in uniform temperatures, the long-period rhythm tends to disappear -- or, perhaps, it is obscured -- when the temperature is changed. Among all the performance records, there is, unfortunately, not a single case from which the persistence or non-persistence of the long-period rhythm can be clearly demonstrated.

P A R T II

LOCOMOTOR RESPONSE OF AMOEBA TO CHANGING TEMPERATURE

INTRODUCTORY

We now pass on to a comparative study of locomotion in Amoeba at different temperatures.

In such a study, we are clearly dealing with an independent variable, time, and with two dependent variables, temperature and rate of locomotion. The first of these dependent variables, temperature, is made arbitrarily dependent upon time by the experimental method employed in this investigation; the second, rate of locomotion, is the one which we are studying. Time evidently affects both of the dependent variables, and, as we have conceived the problem, our purpose is to study the variations in the rate of locomotion which are coincident with controlled variations in temperature.

That the independent variable, time, plays an important part in locomotion, is abundantly clear from what we have seen in the previous section of this paper. If locomotor activity is rhythmic, it must be dependent in some way, upon time. It will follow, therefore, that if rate of locomotion is dependent upon both temperature and time, we cannot discover the real relation of one of these, temperature, upon the rate of locomotion, merely by studying the rate of locomotion at any given cross-section of time. In other words, by the very nature of the problem we are dealing with a tri-dimensional and not with a di-dimensional phenomenon, and there seems to be no way of making it di-dimensional.

Temperature, too, may vary

a) upward or downward;

b) continuously or discontinuously, that is, it may vary by a gradual or a sudden variation, and, if gradual, the gradations may proceed at almost any conceivable rate;

c) slightly, moderately or extremely, that is, the variation itself may vary, from an interval of only a fraction of a degree to the extreme

limits of physiological tolerance;

d) infrequently or frequently, from slight fluctuations every few seconds, to a constantly maintained temperature for any conceivable length of time within the life-limits of the organism.

It is probable that each of these different modes of variation of temperature affects the locomotor activity of Amoeba differently. If this fact be taken in conjunction with the one we have already emphasized, namely that temperature probably affects the locomotion of Amoeba differently, depending upon the particular phase of both its long-period and its short-period rhythm in which the organism happens to be at any given particular instant of time, we are evidently dealing with complications that are not easily unravelled.

This complexity of conditions was not fully realized when the problem was undertaken. Hence, little success could be expected in an attempt at defining definitely the various conditions under which any given rate of locomotion was measured. All that can be done, therefore, in presenting the data on this part of our problem, is to offer such evidence for our general conclusions as is discoverable in the general mass of observational details. It will be realized, of course, that the general conclusions must, therefore, be circumscribed by such limitations as are here outlined.

These difficulties make it all the more imperative, to draw a sharp line between the immediate response of Amoeba at the instant when the temperature is changed and the behavior of Amoeba after a given time interval during which the temperature has been maintained constant. We shall accordingly divide this part of the paper into two main divisions.

1. The Immediate Locomotor Response of Amoeba when the Temperature is changed.
2. Response after Persistence in the Changed Temperature.

Fig. 13
Immediate Locomotor Response to Falling Temperature
a. XXII
b. XXXII
c. XVI
d. XX
e. XXXVIII
Minutes

1. Immediate Locomotor Response of Amoeba at the Time when the Temperature is Changed.

A) Immediate Locomotor Response to a Falling Temperature (Figs. 13, 14)

Figure 13 illustrates some of the observed changes of the rate of locomotion coincident with changes of temperature. In this figure, enlarged sections of the performance graphs of several Amoebae are reproduced. Individual XXII, (Fig. 13,a, Performance Record and Graph XXIII, Observations 93-98) was moving at a rate of 14 mm. per minute while the temperature was at 25 degrees. During one minute, the temperature was changed from 25 to 6 degrees, the rate of the Amoeba during this time changing from 14 to 11 mm. per minute. During the next minute, the rate of the animal dropped to 3 mm. and one minute after the new temperature of 6 degrees had been established, the animal was at rest, and continued in this condition for 5 minutes. Then it made a sudden movement forward at a rate of 6 mm. per minute, only to resume its former condition of rest after three minutes of locomotor activity at gradually diminishing rates.

Individual XXXII (Fig. 13,b, Performance Record and Graph XXXII, Observations 13-18) was moving at a rate of 4.3 mm. per minute while the temperature was 14 degrees. When the temperature was lowered to 6 degrees, the rate was retarded, and for the next one half minute the animal was moving at a rate of 2 mm. then for three minutes at a rate of 1.3 mm. and then for the four ensuing minutes, at a rate of 1 mm. per minute. Then it came to rest.

Individual XVI (Fig. 13,c, Performance Record and Graph XVI, Observations 86-89) was moving at a rate of 2.3 mm. per minute at a temperature of 36 degrees. When the temperature was lowered to 11 degrees, the rate of locomotion was retarded to 2 mm. per minute for 5 minutes, and then the animal came to rest.

Individual XV (Fig. 13,a, Performance Record and Graph XV, Observations 18-21) was moving at a rate of 3.75 mm. per minute at a temperature of 18.5 degrees. While the temperature was being lowered, this rate changed to one of 1.75 mm. per minute, but one minute after the new temperature of 9.5 degrees had been established, the rate was accelerated to 2 mm. per minute for 2 minutes, and then to 4 mm. per minute for the succeeding 2 minutes.

Individual XXXVIII (Fig. 13, e, Performance Record and Graph XXXVIII, Observations 21-25) was moving at a rate of 6 mm. per minute while the temperature was 21 degrees. As the temperature began to drop, the rate was accelerated to 7 mm. per minute. Two minutes after the temperature had reached 9.5 degrees the animal was moving at a rate of 3 mm. per minute for 2 minutes, and then at a rate of 5 mm. per minute for the next minute.

The same diversity of response is illustrated in the behavior of the individuals for which parts of the respective performance graphs are given in Fig. 14. In this figure, five instances in which the temperature was lowered to a less extent than in those illustrated in Fig. 13 are reproduced. Thus, in the case of Individual XL, (Fig. 14,c), the temperature was lowered only one degree, from 21 to 20 degrees. Reference to the complete performance graph of this individual will show that the section of the graph here reproduced was but part of the normal rhythmic movement of this individual, and hence, that probably the lowering of temperature of one degree had no effect on this organism. The rise in rate, therefore, from 3 mm. per minute, at which the animal was travelling just previous to the fall in temperature, to a rate of 5 mm. and then 9 mm. per minute, would probably have taken place even if the temperature had not been changed. In the case of Individual LIII (Fig. 13,d, Performance Record and Graph LIII, Observations 55-59) there was a fall in temperature of one and one half

degrees, but this fall in temperature was coincident with an acceleration of rate. In the case of Individual XXX, (Fig. 17,b, Performance Record and Graph XXX, Observations 13-18) though the temperature fell 2 degrees, from 27 to 25 degrees, the rate fell at first from 9 to 3 cm. per minute, but this fall was followed by an acceleration in the course of which the rate maintained just previous to the temperature change was again reached. Similarly, a fall in temperature of 3 degrees, in the case of Individual XXIII (Fig. 13,a, Performance Record and Graph XXIII, Observations [illegible]-11[illegible]), from 25 to 2[illegible] degrees, and in the case of individual XXIV (Fig. 13,e, Performance Record and Graph XXIV, Observations [illegible]-23) from 33 to 30 degrees, did not affect the normal alternations of accelerations and retardations. In all of the cases mentioned in this paragraph, the fall in temperature probably did not affect the locomotion of the Amoeba during a time interval of from 2 to 5 minutes after the temperature was changed.

From all of the above, the following conclusions regarding the locomotor response of Amoeba at the time when the temperature is changed seem justifiable:

(1) When the temperature is lowered, from a higher temperature to a low one, e.g. from 25 to 6 degrees, or even from 14 degrees to 6 degrees, Amoeba may respond in a variety of ways by a change in the rate of locomotion. This rate may be retarded abruptly, reach zero and then be accelerated. Or, it may be simply retarded, then continue uniform for an interval as long as 6 minutes and then reach zero. Other instances that have not been illustrated justify the statement, that Amoeba may remain in a resting condition for a long time, even for 15 minutes in a temperature of 9.5 degrees, but as this may occur at almost any temperature, there is no guarantee that this is a direct response to the magnitude of the change of temperature.

(2) When the temperature is lowered from a rather high one to one of about 9.8 or 11 degrees,

a) the rate of locomotion of Ameba may be unaffected for sometime after the change.

b) Ameba may come to rest for a brief time and then resume its locomotion.

c) The rate may be retarded for a while, and then accelerated, usually, however, not reaching its previously high value.

(3) When the temperature is lowered through a small temperature interval, but in such a way that both the old and the new temperatures lie near the physiologically optimal condition for the animal, the rate probably remains unaffected.

(4) In general, when the temperature is lowered,

a) through a small temperature interval, the rate of locomotion may not be affected at all;

b) through a greater interval, there may be a direct response, which may show itself in a gradual diminution of the rate, or in a reduction of the rate to zero, or, in rare cases, in an acceleration of the rate.

(5) There is some indication that the "temperature level" from which the lowering takes place has considerable effect upon the character of the response that is elicited from the organism.

Fig. 15
Immediate Locomotor Response to Rising Temperature

B) Immediate Locomotor Response to Rising of Temperature.
(Figs. 15-16)

The immediate response of Ameba to a rise in temperature is no less varied than it is to a fall of temperature.

For the sake of clearness, we shall again distinguish the response to a great rise from that to a smaller rise, meaning, arbitrarily, by a great rise, a change of 8 degrees or more, by a small rise, a change of less than 8 degrees.

Fig. 15 illustrates the response of several Ameba to a great rise in temperature. The difference in response of the same ameba (individually) to a change of temperature of equal magnitude, is made evident by graphs a and b (Fig. 15). In both cases, the temperature was raised to 24 degrees, in the first case (Fig. 15,a) from 9 degrees, in the second (Fig. 15,b) from 10 degrees. At 9 degrees, the animal was moving at a rate of 1.75 mm. per minute. The rate was accelerated to 3.5 mm. per minute as soon as the temperature was raised, and to 18 mm. per minute, only two minutes after the change in temperature had been affected. In the second case, the animal was moving at a rate of 1.7 mm. per minute. The temperature was rising more slowly; it took two minutes to effect the change from 10 to 24 degrees. During this time, the rate of the animal increased at first to 5 and then to 6 mm. per minute and in the next minute it reached a maximum rate of 10 mm. per minute. A comparison of these two cases is all the more instructive, as the temperature level from which the change of temperature took place was almost the same in both cases, namely 9 and 10 degrees, and the rate of locomotion of both amebae at the low temperature was about equal, 1.75 mm. and 1.70 mm. per minute respectively. And yet, despite this equality of change in external condition and the equal locomotor activity of the organism, the response was so much greater in the first case than in the second.

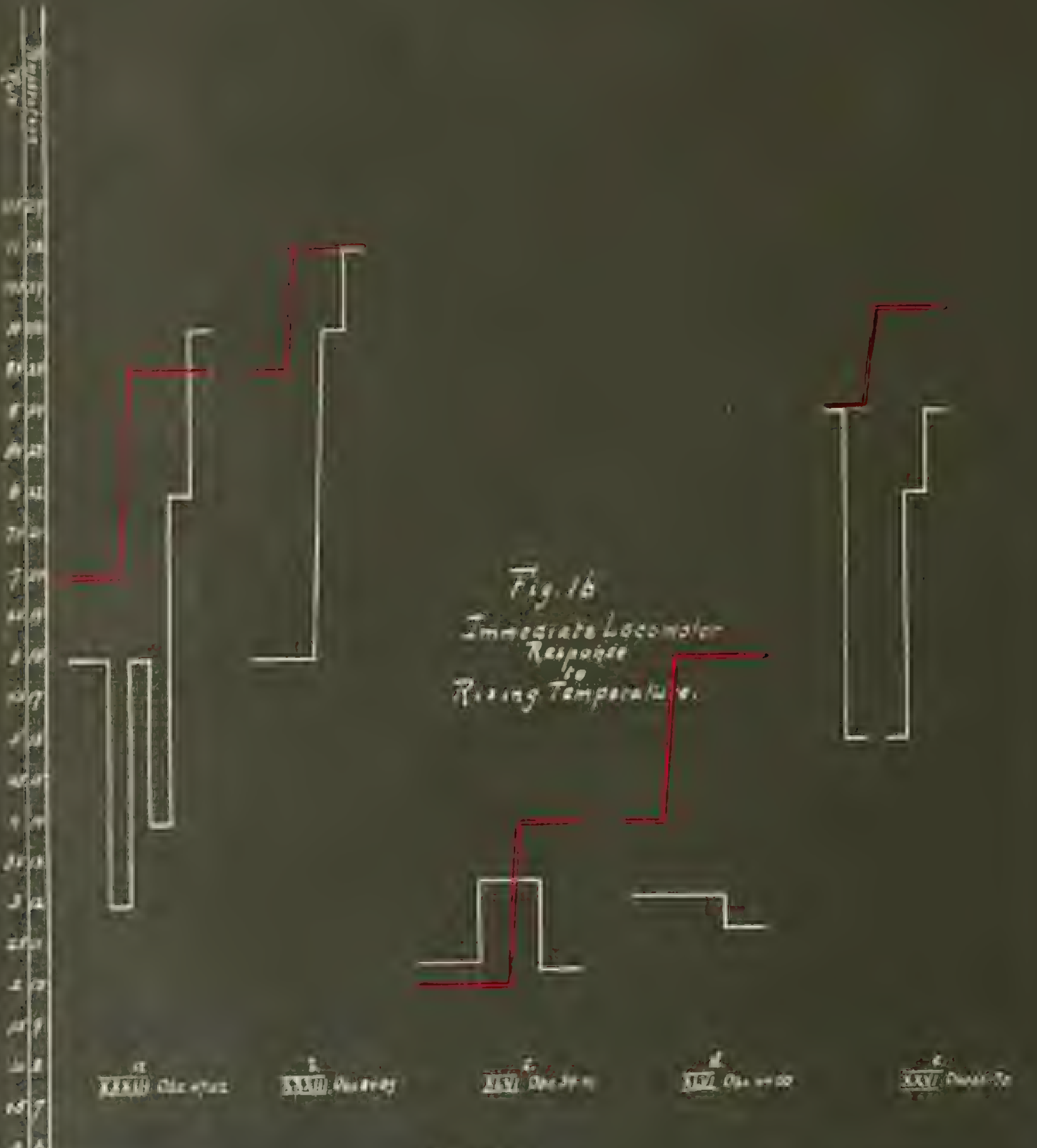


Fig. 1b
Immediate Locomotor Response to Rising Temperature.
Minutes

Individual LVI, (Fig. 15,c, Performance Record and Graph LVI, Observations 36-38) was moving at a rate of 9.3 mm. per minute at a temperature of 16.5 degrees. When the temperature began to rise, the rate of the animal decreased, so that when the temperature had reached 29 degrees, the rate of the amoeba was 3 mm. per minute. This rate continued for 2½ minutes, and then was accelerated to 5.8 mm. per minute. As Individual LVI illustrates a sudden retardation in rate at rising temperature, so Individual LIII (Fig. 15,d, Performance Record and Graph LIII, Observations 91-94) illustrates a sudden acceleration in rate. Immediately after the rise in temperature from 15.5 to 25 degrees, the rate increased from 8 mm. to 15.5 mm. per minute. Individual LIV (Fig. 15,e, Performance Record and Graph LIV, Observations 37-40) on the other hand, was at first retarded in its rate and then rapidly accelerated while the temperature rose from 17 to 25.5 degrees.

The immediate response of Ameba to sudden less extreme changes in temperature is illustrated by the graphs reproduced in Fig. 16. Individual XXIII (Fig. 16,a, Performance Record and Graph XXIII, Observations 47-52) continued its alternation of accelerations and retardations, despite the rise in temperature from 20 to 25 degrees. When the temperature rose from 25 to 28 degrees, however, the rate of same individual (Fig. 16,b, Performance Record and Graph XXXIII, Observations 84-89) was accelerated gradually from 6 to 11 mm. per minute. The rate of Individual XLVI (Fig. 16,c, Performance Record and Graph XLVI, Observations 34-41) was retarded during a rise of temperature from 10 to 14 degrees. The rate of the same individual (Fig. 16,d, Performance Record and Graph XLVI, Observations 44-50) was also retarded during a rise of temperature from 14 to 18 degrees. The rate of Individual XXVI (Fig. 16,e, Performance Record and Graph XXVI, Observations 65-70) was gradually accelerated.

Clearly then, there is no uniformity of the immediate locomotor response when the temperature rises, either through a rather great interval of about 10 degrees, or through a small interval of 3 degrees or less. In general, we may say,

(1) When the temperature rises from a rather low to a higher temperature, Amoeba usually responds by an increase in the rate of locomotion. This increase, however, does not seem to be proportionate to the degree of change of temperature. A change of rate of only 1 or even less millimeters per minute may be coincident with a change of temperature of several degrees.

(2) Sometimes a retardation may ensue after a rise in temperature of about 10 degrees.

(3) The character of the response seems to be independent of the height of the temperature level from which the change takes place.

(4) When the change of temperature is one of only 3 or 4 degrees, the Amoeba may not be affected by it, or it may respond by an increase of rate, or by a decrease of rate.

C. Influence of the Rhythm on the Immediate Response of Amoeba to a Change of Temperature.

A possible explanation of this apparently anomalous behavior of Amoeba has already been insinuated, in our discussion of the rhythm of locomotion. It would seem highly probable a priori, and the suspicion is corroborated by some evidence, that the immediate response of Amoeba to a change of temperature is conditioned, not only by the temperature itself, by the extent of the change, and by the temperature level from which the change takes place, but also by the particular phase of both the long-period and the short-period rhythm, in which the organism happens to be at the instant when the change of temperature takes place. The data at hand at present can do little more than corroborate this suspicion. Thus, we should expect quite a different response, if the temperature is, for example, raised, at the instant when the rate is being accelerated than when the rate is being retarded. Again, if the Amoeba happen to be on the upward grade of the long-period rhythm, it is highly probable that an increase in temperature would produce a greater accelerating effect than when it is moving on the downward grade of the long-period rhythm. This explanation of the extreme variations of immediate response to changing temperatures is not offered as a conclusive one, but only as a probable one, and its truth must depend on the interpretation we have given of the rhythmic character of locomotor activity.

2. LOCOMOTOR RESPONSE OF AMOEBA DURING PERSISTENCE in a CHANGED TEMPERATURE

We have just seen that there is very little uniformity in the immediate response of Amoeba to a change of temperature. There is much greater uniformity, however, in the response of these organisms, if they are allowed to remain in the changed temperature conditions for some time. In general, though the animal may respond to a change of temperature in a multiplicity of ways, still, if the temperature is increased, it will be found that in the course of some little time, the average rate will increase; if the temperature is decreased, the average rate, too, will decrease. The exact quantitative expression of this response we shall discuss in the next part of this paper, when we treat of the measure of the dependence of rate of locomotion on temperature.

The general statement we have just made of the dependence of the average rate of locomotion on temperature is in complete harmony with general physiological behavior. The immediate response of an animal to a change of environment is usually characterized by an "abnormal" mode of behavior. It is only when the animal has acclimatized itself to the new set of conditions, that it can act "normally" again. The prevalence of "shock reactions" in widely diverse forms, is but another illustration of this same physiological fact. A "shock reaction" is only temporary, and after the "shock" has been dissipated, the organism usually resumes its "normal" mode of behavior, unless the conditions are found to be too extreme.

We can best study the effect of the persistence of Amoeba in a changed temperature, by comparing the average rates of locomotion in different constant temperatures. We may do this,

a) by comparing the average rates of locomotion of the same individual

in different constant temperatures; and

B. by comparing the average rates of locomotion of several individuals in different constant temperatures.

A. Comparative, Average Rates of Locomotion of the Same Individual
at
Different Constant Temperatures.

In the course of this investigation, it was frequently possible to subject the same individual to a number of different temperatures. Thus, Individual XIV was studied at 19.5 and at 20 degrees; Individual XLIII was studied at 20, 10.5, 12, 15.5, 16 and 10.5 degrees; Individual LII, at 18 and 22 degrees; Individual LV, at 26, 24 and 20 degrees. Clearly, if we determine the average rate of locomotion maintained by a given individual while it was subjected to a given temperature, and then compare this rate with that maintained by the same individual at a different temperature, we may arrive at a fairly accurate measure of the effect of temperature upon the rate of locomotion.

The average rate of locomotion per minute at a given temperature may be determined by dividing the total distance traversed by an individual by the number of minutes during which it was under observation under that particular condition. The information necessary for this may easily be found from the performance records, and it has been summarized in Table XIV. This table enables us to compare the average rates of locomotion of all the Amoebae studied at different constant temperatures. Column 1 gives the designation of the individual; Column 2, the temperature in degrees C maintained during a given set of observations; Column 3, the total distance, in mm. traversed by an individual during the time interval given in Column 4; Column 5 finally gives the average rate in mm. per minute.

An inspection of the table will show that many of the individuals illustrate the general fact that the rate increases with rising temperature. Individual [illegible], for example, moved at a rate of [illegible] per minute at [illegible], and at a rate of 5.67 mm. per minute at 26 degrees. Individual LII moved at a rate of 6.72 mm. per minute at 18 degrees, and at a rate of [illegible] mm.

T A B L E [illegible]

Average Rates of Locomotion of [illegible] Amoebae at Different Constant Temperatures.
Summarized from the Performance Records (see Appendix)

Column 1 - Designation of the Individual (Roman Numerals).

Column 2 - The temperature maintained during a series of observations.

Column 3 - The total distance traversed by an individual during the interval of time given in Column 4.*

Column 4 - The time interval during which an individual was observed at the stated temperature.

Column 5 - The average rate per minute, in mm.*

*Apparent values - To reduce to real values, divide by [illegible] - (see p. [illegible]).

T A B L E XIV

1 Designation of the Individual	2 Temperature Degrees C	3 Total Distance Mm.	4 Time Interval Min.	5 Rate Mm. per Min.
I	9	30.0	22	1.36
	24	55.0	7	7.86
	10	18.5	14	1.32
	24	30.5	4	7.63
	10	10.5	10	1.05
	26	25.5	3	8.50
	10	7.5	4	1.88
II	15	33.5	5	6.70
	10	38.0	10	3.80
	20	58.5	7	8.36
III	22	71.0	8	8.87
	10	63.25	39	1.62
	25	44.5	4	11.10
	11	79.5	28	2.84
	25	59.0	7	8.43
	11	28.5	26	1.10
V	20	32.0	4	8.00
	10	24.5	16	1.53
	25	44.0	6	7.33
	10	20.0	9	2.22
	20	48.0	7	6.86
	10	33.0	8	4.13
	6	25.0	9	2.78
	20	50.5	7	7.21
VI	20	85.5	8	10.69
	9.5	31.0	16	1.94
	24	99.0	13	7.62
	10	35.0	16	2.20
	24	89.5	8	11.20
	10	11.5	20	.58
	20	51.5	8	6.44
	10	28.0	12	2.33
	24	22.5	5	4.50
IX	18	11.0	5	2.20
	25.5	43.0	9	4.78
	24	15.5	2	7.75
	10.5	34.0	30	1.13
	24.5	41.0	12	3.42
	14.5	5.0	6	.83

1 Designation of the Individual	2 Temperature Degrees C	3 Total Distance Mm.	4 Time Interval Min.	5 Rate Mm. per Min.
X	19.5	40.0	7	5.71
	10.5	9.5	9	1.06
	10	15.5	5	3.10
	23.5	31.0	4	7.75
	11.5	14.5	8.75	1.66
	24	34.0	4	8.50
	15	32.0	20	1.60
XI	15.5	48.5	6	8.10
	11	36.0	10	3.60
	23	99.5	11	9.04
	10	84.5	19	4.45
	8	32.0	20	1.60
	23	64.0	9	7.10
XII	19.5	418.0	89.46	4.67
XIII	20	139.5	58.75	2.37
	26	34.5	20	1.72
	15	35.0	15	2.33
	16	10.5	4.5	2.33
	14	20.0	8	2.50
	24	15.0	5	3.00
XIV	20	36.5	29	1.26
	19.5	9.0	8	1.10
XV	18	11.5	4	2.90
	18.5	96.0	29	3.31
	10.5	97.5	31	3.15
	11	149.5	44	3.40
	10	23.5	22	1.07
	10.5	11.0	7	1.57
	10	33.5	40	.84
	26	7.5	12.5	.60
XVI	20	100.5	46	2.18
	26	41.0	10	4.10
	27	17.5	3	5.80
	26	15.0	2	7.50
	24	42.0	7	6.00
	26	9.0	2	4.50
	28	12.0	2.5	4.50
	26	44.0	5	8.80

1 Designation of the Individual	2 Temperature Degrees C	3 Total Distance Mm.	4 Time Interval Min.	5 Rate Mm. per Min.
XVI	30	95.0	14.46	6.57
	28	88.5	17.66	5.01
	11	16.0	57.5	.28
	8	73.5	49	1.50
	16	33.5	10	3.35
	20	79.5	18.25	4.37
XVII	20	230.5	35.24	6.54
	15	134.0	83	1.61
	15.5	20.0	21	.95
	20.5	41.5	34.5	1.20
XVII (a)	15	36.5	20	1.83
XVIII	20	179.5	67.5	2.66
	16	370.0	115	3.22
	20	100.0	28.5	3.50
XIX	20	144.5	44	3.30
XX	20	129.0	51.5	2.50
	11	64.0	45	1.42
XXI	22.5	271.5	48.5	5.59
	26	317.5	56	5.67
XXII	22	304.0	29	10.48
	25	615.0	55.5	11.08
	6	14.0	6	2.33
XXIII	22.5	84.0	11	7.64
	22	35.0	3	11.67
	20	152.0	28.5	5.33
	25	331.0	32.06	10.32
	28	172.0	19	9.00
	25	96.0	11.5	8.35
	23	23.0	5	4.60
	15	28.0	5	5.60
XXIV	23	236.0	27.5	8.58
	20	289.0	30.5	9.48

1 Designation of the Individual	2 Temperature Degrees C	3 Total Distance Mm.	4 Time Interval Min.	5 Rate Mm. per Min.
XXV	20	73.0	9	8.10
	17	169.5	27.25	6.20
	16	8.0	29	.28
XXVI	21	194.0	26	7.47
	24	175.0	34	5.15
	26.5	104.0	19	5.47
	23	34.0	14.5	2.35
	19	64.0	33.5	1.91
	20	32.0	7	4.57
XXVII	21	204.0	29	7.03
	15	69.0	13	5.30
XXVII (a)	21	171.0	23.5	7.28
XXVIII	21	113.5	27.5	4.13
	23	28.5	6.75	4.22
	24	123.0	23	5.30
	27	30.5	6.66	4.60
	28	37.5	6	6.25
	30	29.0	5.5	5.30
	32	22.0	5	4.40
	23	6.0	2	3.00
XXVIII (a)	24	30.0	3.65	8.22
	28	41.0	6	6.83
XXIX	21	63.0	14	4.50
	18	31.0	12	2.58
XXX	20	171.0	27	6.33
	25	122.0	27	4.52
	27.5	95.0	13	7.30
	22	160.5	15	10.70
	20	98.5	16	6.16
	16	12.0	2	6.00
	15	144.5	29	4.98
	27	30.0	12	2.50
XXXI	20	142.5	40	3.56
	27	66.0	6	11.00
	25	173.5	23.5	7.38
	15	16.0	3	5.33

1 Designation of the Individual	2 Temperature Degrees C	3 Total Distance Mm.	4 Time Interval Min.	5 Rate Mm. per Min.
XXXII	14	73.0	30	2.43
	6	21.0	28.5	.74
	20	18.0	8	2.25
XXXIII	20	102.5	29.5	3.47
	26	85.0	9.25	9.19
XXXIV	26	111.0	17.58	6.31
XXXV	22	222.0	33	6.73
	17.5	16.0	4	4.00
	17	76.0	21	3.62
	19	77.0	15	5.13
	9.5	5.5	11	.50
	10.5	46.0	13.16	3.50
XXXVI	20	237.0	31	7.60
XXXVII	21	40.0	16	2.50
	15	16.5	14	1.18
XXXVIII	21	137.0	19	7.20
	9.5	83.5	34	2.46
	16	48.5	18	2.70
	9.5	8.0	6	1.33
	14	14.0	7	2.00
	17.5	16.0	8	2.00
XXXVIII (a)	16	58.0	20	2.90
XXXIX	19.5	134.5	24.96	5.39
	11	5.0	6	.83
	12	9.5	3	3.20
	13	10.0	4	2.50
	14	19.0	8	2.38
	15	73.0	22	3.32
	12	23.0	10	2.30
XL	21	96.5	17	5.70
	20	134.5	22	6.11
	12.5	120.0	28	4.28

1 Designation of the Individual	2 Temperature Degrees C	3 Total Distance Mm.	4 Time Interval Min.	5 Rate Mm. per Min.
XL	9	10.5	7	1.50
	9.5	7.0	5	1.40
	10.5	43.0	14.75	2.92
	15	59.0	21	2.80
XLI	22	181.5	23	7.89
	21.5	100.0	8	12.50
	10	10.0	6	1.66
	11	8.0	7.5	1.07
	13	179.0	43.5	4.11
	15	77.0	26	2.96
	20.5	55.0	20	2.75
	29	6.0	2	3.00
	27	83.0	23.5	3.53
	19.5	13.0	10.5	1.24
	14	15.0	4	3.75
XLII	20	22.0	3	7.30
	16.5	7.0	2	3.50
	16	107.0	23	4.65
XLIII	20	90.0	25	3.60
	10.5	42.5	24.5	1.73
	12	12.0	16	.75
	15.5	26.0	15	1.73
	20	101.0	23.5	4.30
	16	44.5	30.5	1.46
	10.5	5.0	9	.56
XLIV	18	83.0	20	4.15
	16	62.5	16	3.90
	16	2.0	2	1.00
	16	6.0	2	3.00
	13.8	8.0	7	1.14
XLV	17	70.0	15.5	4.52
	12.5	50.0	21	2.38
	14	19.0	10	1.90
	15	20.0	4	5.00
	13.8	15.0	6	2.50
	12	32.5	22	1.50
	11	13.0	30	.43
	13	14.5	31	.47

1 Designation of the Individual	2 Temperature Degrees C	3 Total Distance Mm.	4 Time Interval Min.	5 Rate Mm. per Min.
XLVI	14	84.5	18	4.70
	14.5	67.0	12	5.58
	10	14.0	4	3.50
	12	16.0	9.5	1.68
	10	33.5	20	1.68
	14	62.0	19	3.26
	18	118.5	28.5	4.16
	16	118.0	28	4.22
XLVII	18	379.0	42.4	8.94
	25.5	168.0	19.1	8.80
	13.5	82.0	21	3.90
	19	102.0	10.05	9.70
XLVIII	20.5	72.0	11	6.55
	16	26.0	4.5	5.78
	8.5	3.0	1.5	2.00
	14	31.0	8.5	3.65
	15.5	39.0	15.5	2.60
	21	10.0	5	2.00
XLIX	18	70.5	16	4.40
	12.5	33.0	16	2.06
	14	26.0	16	1.63
L	21	18.0	9.5	1.90
	18	89.0	42	2.10
LI	19	103.0	24.5	4.20
	16.5	112.5	35	3.21
	13.5	71.5	22.5	3.18
	15.5	23.0	8	2.88
	14.5	28.5	10	2.85
	10.5	7.5	11.75	.64
	12.5	24.5	19	1.29
	15	14.5	7.5	1.93
LII	18	181.5	27	6.72
	22	129.0	15.5	8.32
LIII	18	33.0	6	5.50
	19	118.0	15.5	7.61
	22	149.5	16	9.35
	27	86.0	20.5	4.19

1 Designation of the Individual	2 Temperature Degrees C	3 Total Distance Mm.	4 Time Interval Min.	5 Rate Mm. per Min.
LIII	25.5	86.5	20.5	4.22
	24	82.5	23	3.60
	17	184.5	35.5	5.20
	25	54.0	9	6.00
LIV	19	27.0	4	6.75
	24	183.0	20.5	8.93
	17	101.0	25.5	3.96
	25.5	197.0	17.5	11.30
	27.5	88.5	18	4.90
	26.5	149.0	17	8.76
LV	26	74.5	12.5	5.96
	28	138.0	34.5	4.00
	24	108.0	23.5	4.60
	28	87.0	18	4.83
LVI	18	218.5	28.5	7.66
	16.5	206.0	28.6	7.20
	29	158.5	29.5	5.37
	26	67.0	12	5.58
	23	32.0	9	3.56
	21	97.0	21	4.62
	20	14.0	4	3.50
LVII	19.5	135.0	31.5	4.29
	16	56.5	23.5	2.40
	18	28.0	14	2.00
LVIII	22	203.0	37.5	5.40
LIX	20	37.5	7.5	5.00
	21.5	132.5	24	5.52

per minute at 22 degrees.

Similarly, we find abundant confirmation of the general statement that the rate of amoeba decreases with falling temperature. Thus, Individual XX moved at a rate of 5.50 mm. per minute at 20 degrees and at a rate of 1.42 mm. per minute at 11 degrees. Individual XXVII moved at a rate of 7.03 per minute at 21 degrees and at a rate of 5.20 mm. per minute at 15 degrees.

In these several instances, we have mentioned individuals that were observed at two temperatures only. Individuals which were observed at several temperatures, also, even when periods of rising alternated with periods of falling temperatures, may illustrate the general conclusion. Thus, Individual XXXV was subjected successively to 22 degrees for 53 minutes, to 17.5 degrees for 4 minutes, to 17 degrees for 21 minutes, to 19 degrees for 15 minutes, to 9.5 degrees for 11 minutes and finally to 10.5 degrees for 13.16 minutes. During these various periods, the average rate varied in the same way as the temperature, the rates being successively, 6.73, 4.00, 3.62, 5.13, 9.59 and 3.50 mm. per minute.

Such instances of regularity in the changes of value of the average rates of locomotion with temperature were rather frequent, but divergencies from such regularity were much more frequent, especially when the same individual was subjected to a series of temperatures. As an illustration of this point, we may compare the average rates at which Individual XXXIII moved. As the temperature rose from 21 to 23 and then to 24 degrees, the rate increased from 4.17 mm., then to 4.33 mm. and then to 5.50 mm. per minute. A further rise in temperature, however, to 27 degrees, did not effect an increase in rate, but rather a decrease below that maintained at 21 degrees, namely a decrease to 3.80 mm. per minute. As the temperature rose to 28 degrees, the rate also increased but, again, a further increase in

temperature to 30 degrees, and then to 32 degrees, brought about a further reduction in rate of 5.30 and 4.40 mm. per minute. At a final temperature of 23 degrees, the animal was moving at a rate of 3.00 mm. per minute, much more slowly than it did at 21 degrees at the beginning of the experiment.

This instance is instructive for several reasons. The time intervals for which these various rates were determined were rather brief, being only 5 and 6 minutes except in the case of temperatures, 21 and 24 degrees. It is probable that the record of the locomotor activity of this individual would have been considerably modified, if it had been observed for, say, half an hour in each temperature. In this case, again, the same caution must be given, which has been repeated so often before, that a considerable time interval must be allowed to elapse before we can make a definite statement about the locomotor activity of this organism. It is probable that many of the anomalous cases of this character which may be found in the table we are studying, may find their explanation in the fact that the effects of the temperature were masked by the rhythm, and that the time intervals during which the observations were made were too short to enable the average rate to efface effectively the variations due to such periodicity.

The instance of Individual XXVIII which we are discussing might lead to the further suspicion that a decreasing rate of locomotion even at a rising temperature may be due to a prolongation of the period of locomotor activity. We should expect, in other words, that the animal would be less responsive to a change of environment after a prolonged period of locomotor activity. That this is not necessarily the case, is shown by the record of Individual [illegible]. After it had been observed for 27 minutes, at temperatures of 2[illegible], 25 and 27.5 degrees, it attained a rate at [illegible] degrees which was much higher than any previous one.

Hence, for the same individual subjected to various temperatures,

(1) The average rate of locomotion for prolonged time intervals usually increases with rising and decreases with falling temperature.

(2) At times, however, an increase in the temperature may be followed by a decrease in the average rate, and a decrease in temperature, by an increase in the average rate.

(3) The average rate of locomotion in a series of successive changing temperatures may exhibit decided anomalies.

B. Comparative Average Rates of Locomotion of All Individuals at Different Constant Temperatures.

To make the general trend of the results of this investigation more obvious, Table XIV, in which the average rates of locomotion at constant temperatures of all of the amoebae used in this study were grouped under the respective designation of the individuals, has been recast. Table XV, therefore, embodies the same data that were presented in Table XIV, with this difference, however, that in Table XV the data are grouped under the various temperatures at which studies were made. The data given in this table are plotted in Fig. 17. In this figure, temperatures are plotted as abscissas, and rates of locomotion as ordinates, and each average rate which is listed in Table XV is indicated along the ordinate for its proper temperature by a small circle.

a) Value, as Evidence, of the Whole Mass of Data

Since Table XV and Fig. 17 embody, explicitly or implicitly, all the observations that were made on the effect of temperature on the rate of locomotion, it might be well to comment, first of all, on some of the purely "mechanical" details of our mass of data, on their value, as evidence in this investigation. Two hundred and seventy-eight average rates are presented in Table XV and are plotted in Fig. 17. These average rates were determined from the study of 62 amoebae, at [illegible] different temperatures, practically at all half-degree intervals, between [illegible] and [illegible] degrees.

It will be noted in Fig. 17 that a great many more average rates are given for some of the temperatures than for others. Thus, to take extreme cases, for 20 degrees, 31 average rates are plotted, while for 15.5 degrees only one average rate is plotted. It will be noted that in general many more readings are given for the whole than for the half degree temperatures. The reason for this unevenness in the data is the obvious


Fig.17
Average Rates at All Temperatures of All Amoebae
Average Rate of one Individual at a given constant Temperature
R
a
t
e
i
n
m.
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
6°
7°
8°
9°
10°
11°
12°

T A B L E XV

Temperatures at which the Rate of Locomotion
of Amoebae were Observed

Column 1 - The Temperature

Column 2 - Designation of the Individuals

Column 3 - Total Distance Traversed at the Stated Temperature*

Column 4 - Duration of the Period of Locomotion

Column 5 - Average Rate of Locomotion*

*In these columns, apparent values are given - To reduce to actual values, divide by 64 (see p. 28).

T A B L E XV

Temperature Degrees C	No. of Individual	Total Distance Mm.	Time Interval Min.	Rate Mm. per Min.
6	V	25.0	9	2.78
"	XXII	14.0	6	2.33
"	XXXII	21.0	28.5	.74
8	XI	32.0	20	1.60
"	XVI	73.5	49	1.50
8.5	XLVIII	3.0	1.5	2.00
9	I	30.0	22	1.36
"	XL	10.5	7	1.50
9.5	VI	31.0	16	1.94
"	XXXV	5.5	11	.50
"	XXXVIII	83.5	34	2.46
"	XLVIII	8.0	6	1.33
"	XL	7.0	5	1.40
10	I	18.5	14	1.32
"	I	10.5	10	1.05
"	I	7.5	4	1.88
"	II	38.0	10	3.80
"	III	63.25	39	1.62
"	V	24.5	16	1.53
"	V	20.0	9	2.22
"	V	33.0	8	4.12
"	VI	35.0	16	2.20
"	VI	11.5	20	.58
"	VI	28.0	12	2.33
"	X	15.5	5	3.10
"	XI	84.5	19	4.45
"	XV	23.5	22	1.07
"	XV	33.5	40	.83
"	XLI	10.0	6	1.66
"	XLVI	14.0	4	3.50
"	XLVI	33.5	20	1.67
10.5	IX	34.0	30	1.13
"	X	9.5	9	1.05
"	XV	97.5	31	3.14
"	XV	11.0	7	1.57
"	XXXV	46.0	13.16	3.50
"	XL	43.0	14.75	2.92

Temperature Degrees C	No. of Individual	Total Distance Mm.	Time Interval Min.	Rate Mm. per Min.
10.5	XLIII	42.5	24.5	1.73
"	XLIII	5.0	9	.55
	LI	7.5	11.75	.64
11	III	79.5	28	2.84
"	III	28.5	26	1.10
"	XI	36.0	10	3.60
"	XV	149.5	44	3.40
"	XVI	16.0	57.5	.28
"	XX	64.0	45	1.42
"	XXXIX	5.0	6	.83
"	XLI	8.0	7.5	1.07
"	XLV	13.0	30	.43
11.5	X	14.5	8.75	1.66
12	XXXIX	9.5	3	3.20
"	XXXIX	23.0	10	2.30
"	XLIII	12.0	16	.75
"	XLV	32.5	22	1.50
"	XLVI	16.0	9.5	1.68
12.5	XL	120.0	28	4.28
"	XLV	50.0	21	2.38
"	XLIX	33.0	16	2.06
"	LI	24.5	19	1.29
13	XXXIX	10.0	4	2.50
"	XLI	179.0	43.5	4.11
"	XLV	14.5	31	.47
13.5	XLVII	82.0	21	3.90
"	LI	71.5	22.5	3.17
13.9	XLIV	8.0	7	1.14
"	XLV	15.0	6	2.50
14	XIII	20.0	8	2.50
"	XXXII	73.0	30	2.43
"	XXXVIII	14.0	7	2.00
"	XXXIX	19.0	8	2.38
"	XLV	19.0	10	1.90
"	XLVI	84.5	18	4.70

Temperature Degrees C	No. of Individual	Total Distance Mm.	Time Interval Min.	Rate Mm. per Min.
14	XLVI	62.0	19	3.65
"	XLVIII	31.0	8.5	3.64
"	XLIX	26.0	16	1.63
"	XLI	15.0	4	3.75
14.5	IX	5.0	6	.83
"	XLVI	67.0	12	5.58
"	LI	28.5	10	2.85
15	II	33.5	5	6.70
"	X	32.0	20	1.60
"	XIII	35.0	15	2.33
"	XVII	134.0	83	1.61
"	XVII (a)	36.5	20	1.83
"	XXIII	28.0	5	5.60
"	XXVII	69.0	13	5.30
"	XXX	144.5	29	4.98
"	XXXI	16.0	3	5.33
"	XXXVII	16.5	14	1.18
"	XXXIX	73.0	22	3.32
"	XL	59.0	21	2.80
"	XLI	77.0	26	2.96
"	XLV	20.0	4	5.00
"	LI	14.5	7.5	1.93
15.5	XI	48.5	6	8.10
"	XVII	20.0	21	.95
"	XLIII	26.0	15	1.73
"	XLVIII	39.0	15.5	2.60
"	LI	23.0	8	2.87
16	XIII	10.0	4	2.33
"	XVI	33.5	10	3.35
"	XVIII	370.0	11.5	3.22
"	XXV	8.0	29	.28
"	XXX	12.0	2	6.00
"	XXXVIII	48.5	18	2.70
"	XXXVIII (a)	58.0	20	2.90
"	XLII	107.0	23	4.65
"	XLIII	44.5	30.5	1.46
"	XLIV	79.5	[illegible]	3.52
"	XLVI	118.0	28	4.21
"	XLVIII	26.0	4.5	5.77
"	LVII	56.5	23.5	2.40

Temperature Degrees C	No. of Individual	Total Distance Mm.	Time Interval Min.	Rate Mm. per Min.
16.5	XLII	7.0	2	3.50
"	LI	112.5	35	3.21
"	LVI	206.0	28.6	7.20
17	XXV	169.5	27.25	6.20
"	XXXV	76.0	21	3.62
"	XLV	70.0	15.5	4.52
"	LIII	184.5	35.5	5.20
"	LIV	101.0	25.5	3.96
17.5	XXXV	16.0	4	4.00
"	XXXVIII	16.0	8	2.00
18	IX	11.0	5	2.20
"	XV	11.5	4	2.90
"	XXIX	31.0	12	2.58
"	XLIV	83.0	20	4.15
"	XLVI	118.5	28.5	4.16
"	XLVII	379.0	42.4	8.94
"	XLIX	70.5	16	4.40
"	L	89.0	42	2.10
"	LII	181.5	27	6.72
"	LIII	33.0	6	5.50
"	LVI	218.5	28.5	7.66
"	LVII	28.0	14	2.00
18.5	XV	96.0	29	3.31
19	XXVI	64.0	33.5	1.91
"	XXXV	77.0	15	5.13
"	XLVII	102.0	10.05	9.70
"	LI	103.0	24.5	4.20
"	LIII	118.0	15.5	7.61
"	LIV	27.0	4	6.75
19.5	X	40.0	7	5.71
"	XII	418.0	[illegible]	4.67
"	XIV	9.0	8	1.10
"	XXXIX	134.5	[illegible]	[illegible]
"	XLI	13.0	10.5	1.23
"	LVII	135.0	31.5	4.29
20	II	58.5	7	8.36
"	V	32.0	4	8.00
"	V	[illegible]	7	[illegible]
"	V	50.5	7	7.21

Temperature Degrees C	No. of individual	Total Distance Mm.	Time Interval Min.	Rate Mm. per Min.
20	VI	85.5	8	10.69
"	VI	51.5	8	6.44
"	XIII	139.5	58.75	2.37
"	XIV	36.5	29	1.26
"	XVI	100.5	46	2.18
"	XVI	79.5	18.25	4.37
"	XVII	230.5	35.24	6.54
"	XVIII	179.5	67.5	2.66
"	XVIII	100.0	28.5	3.50
"	XIX	144.5	44	3.30
"	XX	129.0	51.5	2.50
"	XXIII	152.0	28.5	5.33
"	XXIV	289.0	30.5	9.48
"	XXV	73.0	9	8.10
"	XXVI	32.0	7	4.57
"	XXX	171.0	27	6.33
"	XXX	98.5	16	6.16
"	XXXI	142.5	40	3.56
"	XXXII	18.0	8	2.25
"	XXXIII	102.5	29.5	3.46
"	XXXVI	237.0	31	7.60
"	XL	134.5	22	6.11
"	XLII	22.0	3	7.30
"	XLIII	90.0	25	3.60
"	XLIII	101.0	23.5	4.30
"	LVI	14.0	4	3.50
"	LIX	37.5	7.5	5.00
20.5	XVII	41.5	34.5	1.20
"	XLI	55.0	20	2.75
"	XLVIII	72.0	11	6.55
21	XXVI	194.0	26	7.47
"	XXVII	204.0	29	7.03
"	XXVII (a)	171.0	23.5	7.28
"	XXVIII	113.5	27.5	4.13
"	XXIX	63.0	14	4.50
"	XXXVII	40.0	16	2.50
"	XXXVIII	137.0	19	7.20
"	XL	96.5	17	5.70
"	XLVIII	10.0	5	2.00
"	L	18.0	9.5	1.90
"	LVI	97.0	21	4.62
21.5	XLI	100.0	8	12.50
"	LIX	132.5	24	5.52

Temperature Degrees C	No. of Individual	Total Distance Mm.	Time Interval Min.	Rate Mm. per Min.
22	III	71.0	8	8.87
"	XXII	304.0	29	10.48
"	XXIII	35.0	3	11.67
"	XXX	160.5	15	10.70
"	XXXV	222.0	33	6.73
"	XLI	181.5	23	7.89
"	LII	129.0	15.5	8.32
"	LIII	149.5	16	9.35
"	LVIII	203.0	37.5	5.40
22.5	XXI	271.5	48.5	5.59
"	XXIII	84.0	11	7.64
23	XI	99.5	11	9.05
"	XI	64.0	9	7.10
"	XXIII	23.0	5	4.60
"	XXIV	236.0	27.5	8.58
"	XXVI	34.0	14.5	2.35
"	XXVIII	28.5	6.75	4.22
"	XXVIII	6.0	2	3.00
"	LVI	32.0	9	3.56
23.5	X	31.0	4	7.75
24	I	55.0	7	7.86
"	I	30.5	4	7.63
"	VI	99.0	13	7.62
"	VI	89.5	8	11.20
"	VI	22.5	5	4.50
"	IX	15.5	2	7.75
"	X	34.0	4	8.50
"	XIII	15.0	5	3.00
"	XVI	42.0	7	6.00
"	XXVI	175.0	34	5.15
"	XXVIII	123.0	23	5.30
"	XXVIII (a)	30.0	3.65	8.22
"	LIII	82.5	23	3.60
"	LIV	183.0	20.5	8.93
"	LV	108.0	23.5	4.60
24.5	IX	41.0	12	3.42
25	III	44.5	4	11.10
"	III	59.0	7	8.43
"	V	44.0	6	7.33
"	XXII	615.0	55.5	11.08

Temperature Degrees C	No. of Individual	Total Distance Mm.	Time Interval Min.	Rate Mm. per Min.
25	XXIII	331.0	32.06	10.32
"	XXIII	96.0	11.5	8.35
"	XXX	122.0	27	4.52
"	XXXI	173.5	23.5	7.38
"	LIII	54.0	9	6.00
25.5	IX	43.0	9	4.78
"	XLVII	168.0	19.1	8.80
"	LIII	86.5	20.5	4.22
"	LIV	197.0	17.5	11.30
26	I	25.5	3	8.50
"	XIII	34.5	20	1.72
"	XV	7.5	12.5	.60
"	XVI	41.0	10	4.10
"	XVI	15.0	2	7.50
"	XVI	9.0	2	4.50
"	XVI	44.0	5	8.80
"	XXXIII	85.0	9.25	9.19
"	XXXIV	111.0	17.58	6.31
"	LV	74.5	12.5	5.96
"	XXI	317.5	56	5.67
"	LVI	67.0	12	5.58
26.5	XXVI	104.0	19	5.47
"	LIV	149.0	17	8.76
27	XVI	17.5	3	5.80
"	XXVIII	30.5	6.66	4.60
"	XXX	30.0	12	2.50
"	XXXI	66.0	6	11.00
"	XLI	83.0	23.5	3.53
"	LIII	86.0	20.5	4.19
27.5	XXX	95.0	13	7.30
"	LIV	88.5	18	4.90
28	XVI	12.0	2.5	4.80
"	XVI	88.5	17.66	5.01
"	XXVIII	41.0	6	6.83
"	LV	138.0	34.5	4.00
"	LV	87.0	18	4.83
"	XXIII	172.0	19	9.00
"	XXVIII	37.5	6	6.25

Temperature Degrees C	No. of Individual	Total Distance Mm.	Time Interval Min.	Rate Mm. per Min.
29	XLI	6.0	2	3.00
"	LVI	158.5	29.5	5.37
30	XVI	95.0	14.46	6.57
"	XXVIII	29.0	5.5	5.30
32	XXVIII	22.0	5	4.40

one, that a consistent effort was made to secure those temperatures which are more easily read on the various thermometers. The half-temperatures are for the most part calculated from the galvanometer deflection, as the thermometer which was used for determining the temperature of the interior of the water chamber could not be read with sufficient accuracy to less than half a degree. For this reason, especially, the temperatures in the reservoirs were always kept as closely as possible to whole-degree readings.

The unevenness in the distribution of the data presented is, however, more apparent than real. For, if larger temperature intervals are considered,

between	6	degrees	and	12.5	degrees,	33	average	rates	are	plotted
"	13	"	"	17.5	"	63	"	"	"	"
"	18	"	"	22.0	"	79	"	"	"	"
"	23	"	"	27.5	"	62	"	"	"	"
"	28	"	"	32.0	"	12	"	"	"	"

Our data are, therefore, least adequate for extreme temperatures. If any justification for this is required, it may well be found in the following facts. At the low temperatures, observation becomes extremely unsatisfactory, owing to the prolonged periods of cessation of activity on the part of Amoeba. It has already been stated that sometimes half an hour or more elapsed before the animal moved any appreciable distance, and these long periods of time are not reckoned with in our data. However, further filling out of the data for locomotion at these low temperatures is extremely desirable. At the higher temperatures, on the other hand, there is imminent danger of killing the animal. Many specimens were lost in this way. Davenport gives the ultra-maximum temperature of Amoeba as 40 to 45 degrees. Even below this temperature, however, there is danger of injuring the animal and the observer must always be fearful, lest he lose an otherwise satisfactory series of observations by the destruction of the Amoeba.

Moreover, in another respect, not evident from Figure 17, but clearly apparent from a more careful study of Table XV , there is lack of uniformity in the evidential value of our data for the entire temperature range. Some of the averages plotted on Figure 17 are averages for very long periods of observation, others for very short periods. To illustrate the point again by extreme cases: At 10 degrees, for example, two of the averages represent observations of only [illegible] minutes duration, while 3, out of the 18 averages presented represent observations of more than 15 minutes duration. Similar statements might be made concerning the average rates at almost any of the other temperatures. This fact, too, is due in a great measure to experimental difficulties. But here, again, the lack of uniformity in the data is not as great as may appear at first sight. Thus, if we select a few of the salient temperatures,

the	averages	for	10	degrees,	represent	observations	of	274.0	minutes	duration
"	"	"	15	"	"	"	"	287.5	"	"
"	"	"	20	"	"	"	"	7[illegible]2.0	"	"
"	"	"	25	"	"	"	"	175.56	"	"

The large preponderance of the observations at 20 degrees is due to the fact that this temperature was usually taken as a starting point for the various experiments.

Again, if we take larger temperature intervals, the lack of uniformity in the data will tend still more to disappear. Thus the observations

between	6	and	12.5	degrees	were	made	during	11[illegible].75	minutes
"	13	"	17.5	"	"	"	"	1070.86	"
"	18	"	22.5	"	"	"	"	1733.37	"
"	23	"	27.5	"	"	"	"	315.05	"
"	28	"	32.0	"	"	"	"	160.12	"

The data, therefore, are sufficiently uniform in distribution to

enable one to draw definite conclusions. More perfect distribution of the observations along the temperature line, would hardly change the general results by more than a fraction of a degree. It is admitted, on the other hand, that while the evidential value of the experimental data is greatest between 10 and 27.5 degrees, more work on the lower and higher temperatures seems desirable to corroborate the conclusions.

b) Outstanding Conclusions from the Whole Mass of Data -

Bearing in mind what has just been said regarding the degree of certainty that must be attached to our conclusions regarding the locomotor activity of Amoeba at various temperatures, the general appearance of the curves in Fig. 17 will suggest the following conclusions:

(1) There is a very clear, upward drift of rates from 6 degrees to approximately 25 degrees.

(2) The maximal average rates increase from 6 degrees to 21.5 degrees, and the curve of maxima is not re-entrant except at a few non-important points.

(3) The minimal average rates, too, show a gradual upward drift, with but few exceptions. It must be borne in mind, however, that zero movement is not plotted on this graph.

(4) By far the larger number of average rates, 87% of all those plotted, lie between 1 and 8 mm. rates per minute.

c) Average Rates of All Individuals at the Same Temperature -

We have thus far used the term "average rate of locomotion" as applied to a single individual moving at a constant temperature. The various average rates plotted in Fig. 17, however, enable us to calculate the average rates of all the various individuals observed at a given temperature. The results of such a calculation are compiled in Table XVI. In successive columns are given ,

(1) the temperature;
(2) the number of individuals studied at that temperature;
(3) the total distance traversed by all these individuals in the stated time interval;
(4) the time interval during which the distance was traversed;
(5) the average rate of locomotion of all the individuals studied at that temperature.

A glance down the column of average rates (Table XVI) will reveal the gradual increase in rate with rising temperature from 6 degrees to

T A B L E XVI

Average Rates of Locomotion for All Individuals
at
All Temperatures

Temperature	No. of Individuals	Distance Traversed Mm.*	Time Interval Min.	Rate per Min. Mm.*
6	3	60.0	43.5	1.38
8	2	105.5	69.0	1.53
8.5	1	3.0	1.5	2.00
9.0	3	43.5	30.5	1.42
9.5	5	135.0	72.0	1.87
10.0	12	504.25	274.0	1.84
10.5	7	296.0	151.2	1.96
11.0	8	399.5	254.0	1.57
11.5	1	14.5	8.75	1.66
12.0	4	93.0	260.5	1.53
12.5	4	227.5	84.0	2.71
13.0	3	203.5	78.5	2.59
13.5	2	153.5	43.5	3.53
14.0	11	386.5	141.5	2.73
14.5	3	100.5	28.0	3.59
15.0	14	788.5	287.5	2.74
15.5	5	156.5	65.5	2.39
16.0	13	962.5	224.0	4.30
16.5	3	325.5	65.6	[illegible]
17.0	5	601.0	124.75	4.82
17.5	2	32.0	12.0	2.66
18.0	12	1254.5	245.4	5.11
18.5	1	96.0	29.0	3.31
19.0	6	491.0	102.55	4.79
19.5	6	749.5	171.42	4.39
20.0	28	3078.0	722.0	4.26
20.5	3	168.5	65.5	2.57
21.0	11	1144.0	207.5	5.51
22.0	9	1455.5	180.0	8.09
23.0	8	523.0	84.75	6.17
23.5	1	31.0	4.0	7.75
24.0	12	1104.5	182.68	6.04
24.5	1	41.0	12.0	[illegible]
25.0	8	1539.0	175.56	8.77
25.5	4	[illegible]	66.1	[illegible]
26.0	5	831.5	162.33	5.17
26.5	2	251.0	36.0	6.98
27.0	6	313.0	71.66	4.36
27.5	2	183.5	31.0	5.92

28.0	5	576.[illegible]	103.66	[illegible]
29.0	2	16[illegible].5	[illegible]1.5	5.22
30.0	2	124.0	19.96	6.20
32.0	1	22.0	5.0	4.40

*Apparent values - To reduce to actual values, divide by [illegible] (see p. [illegible]).

25 degrees, and then a gradual diminution in rate. Between 6 and [illegible] degrees, the prevailing rate is near 1.5 mm.; between [illegible].5 and 15.5 degrees, it is near [illegible].5 mm.; between 16 and [illegible] degrees, it is near [illegible] mm.; between [illegible] and 25 degrees, there is considerable irregularity and between 25 and 31, there is a very evident gradual decline.

These various features are made more obvious by the curve of average rates for the various temperatures, shown in Fig. 17 and designated there as the "curve of averages". For the purpose of simplyfying the curve, not all of the averages have been plotted but only those for whole degrees of temperature.

Obviously, the curve is far from being a smooth one. Though its general tendency is rather clear, still the variations are much more pronounced than one should expect from the number of observations that have been employed in calculating the averages. The same variability which we have had occasion to emphasize all through this paper is again apparent. The abrupt changes in the character of the curve at 1[illegible], 15, 20 degrees may be significant, though thus far no meaning can be attached to them. It will be noted that there is a double maximum, one at 1[illegible] and another at 25 degrees. This is probably due to a lack of sufficiently extensive observation at these two temperatures. The general trend of the curve would seem to indicate that there is a plateau between these two temperatures, and to find this, the averages for 2[illegible] and 2[illegible] degrees, as well as those for 24 and 25 degrees have been combined. The resultant values are plotted in dotted line between 21 and 26 degrees.

d) Average Rates for Five Degree Intervals -

Since the results that have been given, are manifestly extremely variable, a further calculation of averages for five degree intervals may better elucidate the significance of the data. We may employ for this purpose the usual statistical procedure of grouping the data around salient temperatures. Hence, if we consider

as	the	10	degree	group,	all	rates	at	temperatures	between	7.6	and	12.5 degrees
"	"	15	"	"	"	"	"	"	"	12.6	"	17.5 "
"	"	20	"	"	"	"	"	"	"	17.6	"	22.5 "
"	"	25	"	"	"	"	"	"	"	22.6	"	27.5 "
"	"	30	"	"	"	"	"	"	"	27.6	"	32.5 "

the gradual growth of the rate with rising temperature will become more evident. Table XVII exhibits this rearrangement of the data, and the results are graphically represented in Fig. 18.

The rate increases from 1.5 to 5.5 mm. per minute as the temperature rises from 10 to 25 degrees, and then shows a slight decrease. A further discussion of this feature will be given when we study the temperature coefficient in the next part of this paper.

FOLD OUT

T A B L E XVII

Average Rates for Five Degree Intervals.
(Calculated from the Whole Mass of Data)

Temperature Group Degrees C	Actual Temperatures Degrees C.	Total Distance Mm.*	Time Interval Min.	Rate Mm. per Min.*
10	7.5 - 12.5	1881.75	1248.95	1.5
15	13.0 - 17.5	3710.00	1070.85	3.5
20	18.0 - 22.5	8437.00	1733.37	4.9
25	23.0 - 27.5	4312.00	825.05	5.5
30	28.0 - 32.5	886.50	160.12	5.4

*Apparent values - to reduce to actual values, divide by 44 (see p. [illegible]).

C. The Curve of Maximal Rates

We have already intimated that despite the great variation in the rate of locomotion at any temperature, it is possible that temperature fixes a maximum beyond which the rate cannot be accelerated. It is interesting to examine this statement with the accumulated results of this investigation before us. In Fig. 17 the "Curve of Maxima" has been plotted, but to facilitate comparison with the temperature coefficient, it has been redrawn in Fig. 18. The curve for the temperature coefficient will be referred to in the Part III of this paper. The data for this curve are plotted in Table XVIII.

It will be noted that the maximal rate increases progressively from 6 degrees to 24 degrees, thus, paralleling roughly, the curve of averages. Above 24 degrees there is a sharp decline in the curve. Here again, we meet with the same phenomenon which we have already observed in speaking of the curve of averages, an increase in rate to an optimum, and then a decrease. We shall refer again to the possible meaning of all this, when we discuss the temperature coefficient for these maximal rates.

T A B L E XVIII

MAXIMAL RATES AT VARIOUS TEMPERATURES.

Temperature Degrees C	Rates Mm. per Minute
6	[illegible].8
10	4.5
15	6.7
18	8.9
20	10.7
21.5	12.5
24	[illegible]
27	11.0
28	[illegible].6
30	6.5

FOLD OUT

P A R T III

THE MEASURE OF THE DEPENDENCE OF THE RATE OF LOCOMOTION ON TEMPERATURE

---

1. The Temperature Coefficient.
   - A. Historical.
     - a) The Temperature Coefficient of Chemical Reactions.
     - b) The Temperature Coefficient of Biological Processes.
   - B. The Formula for Calculating the Temperature Coefficient.
     - a) Derivation of the Formula.
     - b) Use of the Formula.
     - c) The Meaning of "k" in the Formula, as Applied to Biological Processes.
2. The Temperature Coefficient of the Rate of Locomotion in Amoeba.
   - A. The Temperature Coefficient of the Immediate Locomotor Response to a Change of Temperature.
   - B. The Temperature Coefficient of the Average Rate of Locomotion of One Individual at Different Constant Temperatures.
   - C. The Temperature Coefficient of the Average Rates of Locomotion of Different Individuals at Different Temperatures.
   - D. The Temperature Coefficient of the Average Rate for Five Degree Intervals.
   - E. The Temperature Coefficient of Maximal Rates.
   - F. Summary of the Results from the Various Calculations of the Temperature Coefficient.
3. A Discussion of the Meaning of the Fluctuations in Value of Q_{10} for the Rate of Locomotion.
   - A. Variation in the Value of Q_{10}

B. The High Value of a_{10} at Low Temperatures.

C. The Decreasing Value of a_{10} at Higher Temperatures.

Our purpose in the third part of this paper is to emphasize quantitatively the dependence of the rate of locomotion on temperature.

It has been customary since the early years of the first decade of the present century to express the dependence of various biological phenomena on temperature in terms of a temperature coefficient.

We shall discuss, therefore,

1. The Temperature Coefficient.
2. The Temperature Coefficient of the Rate of Locomotion in Amoeba.
3. The Possible Meaning of the Temperature Coefficient of the Rate of Locomotion in Amoeba.

1. THE TEMPERATURE COEFFICIENT.

A. Historical

a) The Temperature Coefficient of Chemical Reactions.

Wilhelmy, 1850, was the first to attempt a formulation of the dependence of a chemical reaction upon temperature (Kanitz, '15, p. 2). He studied the inversion of cane sugar by acids. It was not until twelve years later, however, that Berthelot succeeded in formulating a rule, which is, even to this day, taken as the basis for all discussions in these matters. He showed that the rate of a chemical reaction is an exponential function of some constant, which varies with different reactions. Views were gradually clarified through the work of A. Vernon Harcourt ('67, '95), Wilhelm Ostwald ('87, '84), William Hecht and A. Conrad ('89) and Arrhenius ('89) until in 1884, J.H. van't Hoff defined the influence of temperature on chemical reaction more accurately and formulated the now current expression of the temperature coefficient rule, namely "A chemical

reaction is accelerated between 2 and 3 times by a rise in temperature of 10 degrees Centigrade". Since that time a large number of chemical reactions have been investigated with critical attention to the limits of applicability of the van't Hoff rule. As the general outcome of all this work, it has been found necessary to modify van't Hoff's rule to some extent. While it was found to be true that the temperature coefficient of by far the greater number of chemical reactions for a ten degree temperature interval lies between the limits of 2 and 3, still some reactions, which are undoubtedly chemical in character have been found with temperature coefficients as high as 5 or 6 and as low as 1.2 or even 1. On the other hand, only very few physical changes are known which have temperature coefficients even approximately as great as those of chemical reactions. The temperature-coefficient as defined by van't Hoff is now usually designated as Q_{10}, and we shall use this designation in the following pages.

Further study of the variability of the temperature coefficient has revealed the fact that its value may change in different reactions, and hence that it is not a universal chemical constant. Interpretations of this phenomenon have not been wanting. Haitan and Kirsch ('13) regard an abnormally high coefficient as indicative of a monomolecular reaction. This view is generally accepted, though the explanation of it must still await the corroboration of one of several rival theories. -- On the other hand, an abnormally low temperature coefficient is regarded as characteristic of reactions in heterogeneous systems, as well as of photochemical reactions. Erich Brunner ('04) and W. Nernst ('04) have sought to establish the diagnostic value of the low temperature coefficient for reactions in heterogeneous systems. The explanation that in such systems the reaction rate is determined not so much by the chemical process itself, but rather by the diffusion of the reacting substances,

seems adequate to account for the observed facts, especially if it is born in mind that the process of diffusion has a low temperature coefficient. The work of Noyes (   ) and Whitney (   ) has probably put this explanation of the low temperature coefficient of reactions in heterogeneous systems, beyond all question.

Johannes Plotnikow ('12), Max Bodenstein ('13) and Fritz Weigert and Otto Kruger ('13) have shown that in photochemical processes the temperature coefficient may be as low as 1.2 or even 1. While the explanation of this phenomenon cannot be considered as definitely established, it is realized that further study on the nature of radiant energy will probably reveal the real meaning of the low temperature coefficient of such reactions.

The value of this coefficient may change, however, not merely in different reactions, but also in the same reaction at different temperatures. Harcourt and Esson ('95) have investigated the action of hydrogen dioxide on potassium iodide in acid media. They find that the temperature coefficient decreases progressively from a value of 2.07 between 0 and approximately 5 degrees, to 1.87 between 45 and 50 degrees. It is considered probable, moreover, that many such instances could be found, if the slow progression of certain chemical reactions and the very rapid rates of others, could be more carefully studied. An explanation of such facts as these must await further research into the nature and efficacy of chemical energy.

In general, therefore, despite the variability of the value of the temperature coefficient, van't Hoff's limits of this value are still accepted. Variations beyond these limits are of so regular a character that they may well be regarded as indicative either of special kinds of reactions, or of limiting conditions in such reactions as otherwise proceed with a normal temperature coefficient.

b) The Temperature Coefficient of Biological Processes.

The first application of the ideas underlying the significance of the chemical temperature coefficient to a biological process was made by Clausen, 1890. He studied the respiration of lupines and wheat seedlings and came to the conclusion that between the limits of 10 and 25 degrees the amount of CO_2 given off during respiration was increased approximately $2\frac{1}{2}$ times for every 10 degree rise in temperature.

Oskar Hertwig, 1898, called attention to the acceleration of the rate of development of the eggs of Rana fusca and Rana esculenta at increasing temperatures and to a corresponding decrease at falling temperatures. He did not try, at the time to apply mathematical calculations to this rate, but promised that he would return to a more rigorous treatment of his data at some future time, a resolve, which, unfortunately, was never carried out.

Shortly after this began a period of ceaseless activity in this particular field of research. J.H. Aberson's work on alcoholic fermentation was published, 1903. In 1903 were published R. Abegg's work on the influence of temperature on the rate of development of the eggs of animals, Karl Peter's work on the acceleration of development in higher temperatures, Aristides Kanitz's work on the influence of temperature on carbon dioxide assimilation, F.F. Blackman's work on optima and limiting factors, Jacques Loeb's work on maturation of the mollusc egg and Snyder's work on the influence of temperature on cardiac contraction. In each of these papers, contributions were made to a further application of the temperature coefficient to biological processes.

Since that time a vast amount of work has accumulated on the relation of the temperature to more than a hundred different biological processes. Kanitz ('15) reviews, three hundred and sixty-five articles dealing with [illegible]

researches, he groups under the following headings: 1. Heartbeat. 2. The Pulsation of Medusae. 3. The Contraction of Smooth Muscle. 4. The Respiration Rhythm. 5. Pulsation of the Vacuoles of Protozoa. 6. Rhythmic Electrical Phenomena. 7. The Velocity of the Nerve Impulse. 8. The Activity of Striated Muscle. 9. The Electromotive Force of Bio-electric Currents. 10. Geotropic and Phototropic Response in Plants. 11. The Streaming of Protoplasm. 12. The Permeability and Resorption Rate of Protoplasm. 13. Toxic Effects. 14. The Length of Life. 15. Developmental Processes. 16. Metabolism in Animals. 17. Metabolism in Plants. 18. The Coagulation of Blood.

In summing up the results of all this work, Kanitz states that there are a large number of physiological processes for which there can be no question of the value or the constancy of the temperature coefficient. The value of Q_{10} for such reactions lies between 2 and 3, and the value is remarkably constant over large ranges of temperature. This is particularly true of rhythmic processes, such as the heart beat, the contraction of smooth muscle, the rhythm of respiration. But other processes as well show this same constancy. Thus the rapidity of toxic influence, the length of life, the velocity of gaseous interchange, geotropic and phototropic presentation time, cleavage rate in eggs, all of these and many others, exhibit a remarkable constancy of the temperature coefficient over large temperature intervals.

There are other biological processes, however, for which the temperature coefficient rises with rising temperature. The rapidity of the production of lethal conditions brought on by various poisons, is such a process. Thus, Theodor, Birstein and [illegible] ('10) have been able to show that the toxic effects of a .01 solution of Sodium Chloride on Staphylococcus pyogenes aureus is accelerated 1.79 times between 1 and 10 degrees, but 2.7[illegible] times between 10 and 17 degrees for every ten degree temperature

interval.

Again, there are biological processes for which there is a noticeable decrease in the value of the temperature coefficient with rising temperature. Carbon dioxide assimilation in plants is an instance in point. Such a fall in the value of the temperature coefficient is characteristic of all processes which show a physiological optimum. As the curve of the reaction rises, the value of the temperature coefficient may fall or remain constant but usually decreases when the reaction has passed its optimum. The change in the value of the coefficient near the physiological temperature-optimum has opened up the large question of the constancy of Q_{10} in biological processes. We have seen that in chemical processes this quantity may be regarded as a constant and when deviations from such a constant value occur, they may for the most part, be explained by the nature of the particular reaction or by the special conditions in which the reaction occurs. In biological processes, however, as we have just seen, large variations in the value of Q_{10} may be found. On the basis of these variations, Krogh goes so far as to deny the constancy of Q_{10}. Other authors have tried to explain these variations. Sutherland ('05) in his work on the temperature coefficient of nerve conduction surmises that the variability of Q_{10} may be due to the fact that conduction is conditioned by many factors and that the velocity of conduction in any temperature may be simply a function of the viscosity of the water. Snyder ('11) subjected this explanation to an experimental test and concluded "after a careful review of the facts at hand, it seems preferable to adhere to the hypothesis put forth in a former paper ('08) that even in certain of the simpler physiological actions we still have to do with at least two distinct chemical actions whose fundamental velocities at any given temperature are different." He concludes further (p. [illegible]) that "the magnitude of the temperature coefficient for differences of 10 degrees Celsius,

them not only for physiological actions but also for many chemical actions. In both orders of phenomena the variation is in the same direction."

The matter is further complicated by the fact that different factors, be they physical or chemical, may affect a given reaction differently at various temperatures within physiological tolerance. Snyder, in the quotation just given, speaks of "at least two distinct chemical actions", but it is quite conceivable that in so complex a system as protoplasm, the interplay of physical and chemical factors may completely mask the effects of any one of them. Pütter, in discussing this question of the variability of Q_{10} calls attention to the fact, that if several factors affect the end result of an accelerated physiological reaction, as happens, for example in many metabolic processes, the slowest factor determines the rate of the entire process. On the other hand, if various factors influence a retarded reaction, the speed with which the end result is obtained is conditioned by the most rapidly acting one. The interplay of such limiting factors are but illustrations of the "Law of Minimum". In accordance, therefore, with the character of the particular factor which dominates a given process at any given moment of time, we should expect an increase or a decrease in the value of the temperature coefficient. It is easy to see from all this why a temperature coefficient may rise at first for a time with increasing temperature and then decrease definitely once the optimum has been reached and passed.

It also becomes apparent from the above, that a fluctuating temperature coefficient is probably indicative of a process that is conditioned by the synergetic operation of a number of factors. If one of these is affected differently from all the others by a change of environment, we have the conditions requisite for irregular or abnormal

response in a reaction which would otherwise be regular and normal. Countless illustrations of the applicability of such a statement will immediately suggest themselves.

In view of the complexity of the phenomena involved in all this, Snyder, ('11, pg. 174) while expressing the expectation "that the ultimate explanation of chemical reaction velocities will be a comparatively simple one", still cautions us that Professor William Ostwald referred to the influence of temperature upon chemical reactions as "one of the darkest chapters in chemical mechanics", and then goes on to say "Although, since Ostwald's opinion was uttered, something has been said also about the influence of temperature upon physiological action, the present author believes that the matter is more complex than even that of chemical reaction, dark as that may be."

The early history of the researches on the value of the temperature coefficient was dominated by the thought that a proof of the chemical character of the vital processes could thus be furnished. It was assumed that since the parallelism between purely chemical and vital processes was emphasized by the equality and constancy of Q_{10} in both kinds of reactions, an argument for the identity or at least the similarity of the two classes of processes could thus be built up. Vant' Hoff's formula was, therefore, taken as a diagnostic sign for recognizing a chemical as distinguished from a physical reaction.

We have already seen the emphasis placed upon this parallelism in the quotation from Snyder ('11, pg. 175) given in a previous paragraph. Loeb, also, while summing up his own and Snyder's work on the temperature coefficient of contraction of strips of heart muscle, says, "These experiments show that the heartbeat is caused by chemical processes which go on constantly." (Loeb, '06). At the time when this was written, no

purely physical phenomenon, with the sole exception of the pressure exerted by steam, was known with a temperature coefficient even approximately as great as those of a chemical reaction. Since that time, however, other such phenomenon have been discovered. Thus, the dissociation equilibrium of weak electrolytes between the limits of 0 and 25 degrees has a Q_{10} of 2.5. The internal friction of glycerin and the electrical conductivity of certain salts in glycerin have the same coefficient. (Davis and Jones, '12).

The discovery of these facts, together with the increasing number of cases in which Q_{10} has been shown to be variable, has been largely influential in changing the attitude of physiologists towards the meaning of the Q_{10}. Thus, Kanitz says, "Die RGT REGEL (Die Reaktionsgeschwindigkeit-Temperatur Regel) befasst sich nicht mit der Konstanz von Q_{10}, sondern nur mit der Grösse der Temperaturabhangigkeit." It is now regarded as a convenient method of measuring the dependence of a given process on temperature. It tells us, in other words, by how many times a reaction is accelerated by a ten degree rise in temperature.

It is in this sense, therefore, that we shall discuss further the temperature coefficient of the rate of locomotion in Amoeba, as a <u>measure of the dependence of the rate upon temperature</u>.

c) The Meaning of "k" in the Van't Hoff Formula,

as Applied to Biological Processes.

The two variable factors in the van't Hoff formula are "t", the temperature, and "k", the rate of the reaction. "t" obviously can have but one meaning, the temperature measured in degree Centigrade. The meaning of "k", however, must necessarily change depending upon the character of the reaction which is being investigated.

In determining the rate of a chemical reaction, we usually measure the amount of a chemical substance transformed in a given time interval. Such a method of measuring the rate of a biological reaction is applicable to many processes, such as the respiratory interchange and metabolic reactions. But there are other reactions in which we could not measure the amount of substance transformed without destroying the living tissue, while, in others again, we should not succeed in making a determination even if the tissue were destroyed.

To give some idea, therefore, of the great number of possible ways in which the rate of a biological process may be determined with a view to their study by means of the van't Hoff formula, the following list of measurable processes has been compiled. Each item in the list has been actually represented by "k" in determining the rate of a particular reaction, by various investigations and the list might easily have been lengthened.

Frequency of the heart beat.
Frequency of excised heart muscle.
Frequency of the dorsal blood vessel.
Pulsation of medusae.
Rhythmical contraction of the oesophagus.
Rhythmical contraction of the stomach.
Frequency of breathing.
Pulsation of vacuoles in protozoa.
Periodicity of the rhythm of electric organs.
Rate of conduction in nerve fibers.
Length of the latent period in muscle.
Duration of muscle action.

Rate of propagation of the contraction wave in muscle.
Magnitude of contraction in muscle.
Stimulation period of muscle.
Length of the presentation time for geotropic and phototropic response in plants.
Rate of protoplasmic streaming.
Rapidity of change of osmotic pressure in plant tissue.
Quantity of water absorbed by tissue.
Length of interval between administration of lethal doses and death.
Duration of periods of narcosis.
Duration of life under various controlled conditions.
Rate of development of eggs.
Length of incubation periods.
Multiplication in protozoa.
Rate of regeneration.
Elongation in the growth of plants.
Amounts of CO_2 eliminated.
Quantities of Oxygen consumed.
Quantities of CO_2 assimilated.
Formation of CO_2 in fermentation.
Coagulation period of blood.

It is obvious that almost any physiological process will lend itself to such studies as we are here discussing. Any quantity of matter, or time interval, or rate of motion, or frequency, involved in a chemical or a physiological reaction, and dependent for its value on temperature may, therefore, be used as "K" in the vant' Hoff formula.

B. THE FORMULA FOR CALCULATING THE TEMPERATURE COEFFICIENT

a) Derivation of the Formula

Various formulae for calculating the temperature coefficient of a chemical reaction for a 10 degree interval have been suggested. The one now in general use, especially in biological literature, is the following:

$$Q_{10} = 10^{\frac{10(\log k_2 - \log k_1)}{t_2 - t_1}}$$

where Q_{10} is the temperature coefficient for a 10 degree interval;

k_2 and k_1 are the rates at temperatures t_2 and t_1, respectively.

This formula may be derived from Berthelot's original formula,

$$k_1 = a \cdot b^{t_1} \tag{1}$$

where k_1 is the rate of the reaction at temperature t_1, and a and b are constants depending upon the nature of the reaction.

Formula (1) may be written,

$$\log k_1 = \log a + t_1 \cdot \log b. \tag{2}$$

If we now let $\log a = A$
and $\log b = B$

we have from (2),

$$\log k_1 = A + B \cdot t_1 \tag{3}$$

Similarly for another temperature t_2, we should have,

$$\log k_2 = A + Bt_2 \tag{4}$$

Subtracting (3) from (4),

$$\log k_2 - \log k_1 = Bt_2 - Bt_1 = B(t_2 - t_1) \tag{5}$$

Hence it follows, that if we can determine experimentally the rate of a reaction at two temperatures t_2 and t_1, we may calculate the constant, B, for then

$$B = \frac{\log k_2 - \log k_1}{t_2 - t_1} \tag{6}$$

For a 10 degree interval, therefore,

$$t_2 - t_1 = 10$$

$$k_2 = k_{t+10}$$

$$k_1 = k_t$$

Substituting these values in (6)

$$\log k_{t+10} - \log k_t = B\,(t + 10 - t) = 10\,B \qquad (7)$$

Or, in other words,

$$\log \frac{k_{t+10}}{k_t} = 10\,B. \qquad (8)$$

Now, if we let $\log Q_{10} = \log k_{t+10} - \log k_t$ (9)

Then, from (8) $\log Q_{10} = \log \dfrac{k_{t+10}}{k_t} = 10\,B$ (10)

and $Q_{10} = \dfrac{k_{t+10}}{k_t} = 10^{10\,B}$ (11)

But from (6) =

$$B = \frac{\log k_2 - \log k_1}{t_2 - t} \qquad (12)$$

Therefore, substituting in (11)

$$Q_{10} = 10^{\frac{10\,(\log k_2 - \log k_1)}{t_2 - t_1}}$$

This formula will be used in calculating the data to be presented in the subsequent pages, and the temperature coefficient for a ten degree interval will be symbolized, as is customary, by Q_{10}.

b) Use of the Formula.

A somewhat elementary discussion of this formula may not be altogether out of place in a paper like this.

It is obvious that if I desire to know by how many times a given reaction is accelerated by a rise in temperature of a given magnitude, all that I need do is to divide the observed rate at one temperature by the observed rate at the other, and the quotient will be the desired value. Hence, if I desire to know by how much a given physiological reaction is accelerated by a ten degree rise in temperature, I need only divide the rate observed at one temperature by the rate observed at a temperature ten degrees higher. In substance, therefore, all that is meant by the van't Hoff temperature coefficient is this, that if such an operation is performed for any given physiological or chemical reaction, the quotient of such a division, if the particular reaction happen to follow this rule, will be found to lie between 2 and 3.

Now obviously, it is not always possible to measure the rate of the same reaction at two intervals exactly ten degrees apart in temperature. Nor is it true, moreover, that if the reaction is measured, say, at five degree intervals, that the quotient which I get by performing the division indicated above, will be one half of that which I would get if the reaction had been measured at temperatures ten degrees apart. For Berthelot has shown that the rate of a chemical reaction varies, not directly as the temperature, but as an exponential function of a constant. To enable one, therefore, to compare the velocity of reactions, even though they be measured at different temperatures and at different temperature intervals, we need some method of reducing our observations to standard conditions, as it were. Van't Hoff's formula gives us such a method for reducing our observations. The meaning of Q_{10} is, therefore, no other than this,

that if I have two reactions, one of which proceeds at the rate k_1 when the temperature is t_1, and the other proceeds at the rate k_2 when the temperature is t_2 then, no matter how close together or far apart t_1 and t_2 may be, IF THOSE REACTIONS WERE TO PROCEED AT THE SAME RATE OVER A TEN DEGREE TEMPERATURE INTERVAL, the ratio of those velocities would have the value actually calculated from the formula for Q_{10}.

It is not necessary, therefore, that I should actually have measured the same reaction at ten degree intervals. I may measure it at two temperature intervals any number of degrees, or any fraction of a degree, apart, and still calculate the value of Q_{10}. The value which I find will then enable me to compare the velocity of this particular reaction with the velocity of any other, with the assurance that I am actually comparing comparable data.

2. THE TEMPERATURE COEFFICIENT OF THE RATE OF LOCOMOTION IN AMOEBA

a. The Temperature Coefficient of the Immediate Locomotor Response to a Change of Temperature

In discussing the immediate locomotor response of Amoeba to a change of temperature, we have emphasized the great variability of behavior both of one individual and of several individuals compared with one another. We have seen that when the temperature changes, the animal may respond by coming to rest immediately or it may continue at the rate of motion which it had before the temperature was changed, or it may accelerate or retard its rate of motion.

Clearly then, no special significance can be attached to a temperature coefficient of a reaction of such variability. The coefficient may vary from infinity to almost finite value.

There is one special case, however, of an immediate response, which deserves mention. The data, unfortunately, are by no means sufficiently ample to enable one to discuss the matter fully. We refer to the response of Amoeba when the temperature is raised but very slightly from a low temperature in which locomotion is just barely perceptible. Individual XXXIX will furnish an illustration. At 11 degrees, it moved for 6 minutes at a rate of .83 mm. per minute. Immediately after the temperature was raised to 12 degrees, its rate was accelerated to 3.20 mm. per minute. If we evaluate the temperature coefficient of such a change of rate by the methods we have described, we should get the enormous value of 722600 for Q_{10}. Similarly, Individual XXXV moved at a rate of .50 mm. per minute at 9.5 degrees, but immediately after the temperature was raised to 10.5 degrees, its rate was accelerated to 3.5 mm. per minute. This change of rate gives a value of 26 million for Q_{10}.

Unusually high temperature coefficients are not entirely unknown in the literature. Thus, Loeb ('08) in his investigation of the duration of life of the eggs of Strongylocentrotus purpuratus at various temperatures found that they could endure a temperature of 25 degrees for a time interval of more than 76 and less than 81 minutes, while they could endure a temperature of 21 degrees for 24 hours. The temperature coefficient of such a change in the duration of life would give a value of 1450 for Q_{10}. Moore's work ('10) on the temperature coefficient of cytolysis of the unfertilized sea urchin egg, leads to similar large values for Q_{10}. One series of experiments gave 3800, another 2300 for the temperature interval 30 to 25 degrees.

We may perhaps, -- if the speculation is allowable -- find an analogy between the cases cited and the change of the rate of locomotion in Amoeba at low temperatures. They seem to have this in common that in both cases we are dealing with organism in peculiarly labile equilibrium. A number of similar physiological processes here suggest themselves. It has often been pointed out that fishes at spawning time are specially responsive to the slightest change of environment (Shelford, '13). If we remember that in this case, as well as in the case of a developing egg we are dealing with physiologically critical conditions, we might make a similar supposition for Amoeba, which is just able to work at a given low temperature. It might possibly, at such a time, be in just such a condition, that the slightest rise in temperature will elicit an unusually large response. All this cannot be admitted as definitely established, however, and more work is desirable to amplify the data. Concomitant evidence, however, for such an interpretation of the phenomenon, is furnished by the fact, that in the present investigation, as well as in many others that might be cited, the temperature coefficient for changes at lower temperatures

is so frequently much greater than it is at higher temperatures. We shall have to return to this point in the discussion.

B. The Temperature Coefficient of the Average Rates of Locomotion of One Individual at Different Constant Temperatures.

We have already seen that while the average rates of locomotion at different temperatures of one individual, when compared with similar rates of other individuals, exhibit considerable variability, this variability is not as great as that of the actually observed rates of locomotion. Similarly, the value of the temperature coefficient of the rates of locomotion of one individual, when compared with those of other individuals, will be much less variable than the temperature coefficients of rates at the moment of change of temperature.

Still, the constancy of Q_{10} in the present investigation is not as definite as one might have been led to expect from the various investigations on similar phenomenon. Even the statement that the average rates of locomotion of a given individual increase in value with rising temperature, or that they decrease with falling temperature, cannot be made absolutely general. Out of 213 temperature changes, 153 average rates, or 60.8% obeyed this rule, while 83 average rates, or 39.2% did not. Much less, therefore, can we speak of a definite factor, by which the rate is accelerated in rising, or retarded in falling temperature.

In Table XIX are given the temperature coefficients for some of the changes in rate. No effort was made at calculating the coefficients for all the changes of temperature that have been given in Table XV, as so many of them are negative, and no special significance has thus far been attached to the magnitude of a negative coefficient. Moreover, in Table XIX, the various temperatures for which the coefficients are calculated do not follow one another in the same sequence in which they were applied to a given individual in an experiment. In calculating the coefficients, many

interfering negative coefficients have been omitted, and only the ratios between the rates at different temperatures, giving positive coefficients, have been included. Our purpose in this table is rather to show by a comparison of the ratios at different temperatures, the extent of constancy or variability of Q_{10}.

The great variability in the value of Q_{10} is made obvious by this table. The values lie between 1.0 and 16.5. On the other hand, out of the 38 determinations given in the table, 19 or 50% lie between 1.5 and 3.5, and 8 or 21% lie between 3.5 and 5.5, while only 6, or 15.8% lie below 1.5 and only 5 or 13.2% lie above 5.5. 27 or 71%, therefore, lie between 1.5 and 5.5. When it is borne in mind that these are the values usually found for the temperature coefficients of by far the greater number of physiological processes, it is clear that we are here dealing with but another illustration of the constancy of the Q_{10}, provided we understand this constancy, not as a rigorously definite mathematical quantity, as it was at one time thought to be, but as one that may vary within more or less wide limits.

T A B L E XIX

THE VALUE OF Q_{10}.

For Average Rates of One Individual
at
Different Constant Temperatures

Individual	Temperature Range Degrees C	Q_{10}
XX	20 - 11	1.90
XXI	22.5- 26	1.00
XXII	22 - 6	2.56
XXIII	22.5- 20	4.22
"	22.5- 25	2.82
"	24 - [illegible]	3.45
"	20 - 28	1.92
XXV	20 - 17	[illegible]
XXVII	21 - 15	1.60
XXVIII	21 - 23	3.48
XXIX	21 - 18	6.39
XXXI	20 - 25	4.10
XXXIII	20 - 26	5.07
XXXV	17.5- 10.5	1.12
"	17 - 19	1.47
"	22 - 19	2.47
XXXVII	21 - 15	[illegible]
XXXVIII	9.5- 16	1.15
"	21 - 16	7.11
XXXIX	12.5- 15	3.40
"	19.5- 15	2.93
XL	21 - 12.5	1.40
"	20 - 12.5	1.58
"	20 - 15	4.76
XLIV	18 - 16	[illegible]
XLVII	25.5- 13.5	1.97
"	13.5- 19	5.24
XLVIII	20.5- 15.5	6.34
XLIX	18 - 12.5	3.97
"	18 - 14	11.97
LII	18 - 22	1.70
LIV	21 - 17	3.19
"	17 - 25.5	3.43
"	17 - 26.5	2.30
"	17 - 27.5	[illegible]
LV	24 - 26	[illegible]
LVII	19.5- 18	16.2
LIX	20 - 21.5	1.93

D. The Temperature Coefficient of the Average Rates of Locomotion of Different Individuals at Different Temperatures.

In discussing Fig. 17, we described the manner in which the "Curve of Averages" was drawn. It was said that the rates of locomotion of all the individuals observed at a given temperature were averaged, by adding their total distance traversed at that temperature and dividing this by the sum of all the time intervals. This method gave the average rate of locomotion of all the individuals observed at that temperature.

If we now determined the temperature coefficients for these values, we should expect a closer correspondence of the coefficients than was found in the previous section. In Table [illegible], we find the results of such a calculation. In the first column are given the temperatures, in the second, the average rates of locomotion for that temperature, in the third, the value of Q_{10}, calculated by using the rate at 6 degrees for a comparison. Unfortunately, there is little uniformity among workers in this field concerning the method of calculating the value of Q_{10}. Some of them use the method of progressive averages, establishing the value of Q_{10}, for rates at successive temperatures; others again, compare all their findings with some basic value. The first method, if employed in the present case gives results of little value, as with rising temperature, so many of the average rates are smaller at a higher than they are at a lower temperature and hence would give a negative coefficient. We have, therefore, compared them all with the slowest rate, which happened to be at the lowest temperature. In other words, in the formula,

$$Q_{10} = 10^{\frac{10(\log k_2 - \log k_1)}{t_2 - t_1}}$$

t_1 has always been taken as 6 degrees,

k_1 " " " " " 1.38 mm. the rate at 6 degrees.

T A B L E XL

THE VALUE OF Q_{10}.

For Average Rates of Locomotion of All Individuals
at
Different Temperatures

Temperature Degrees C	Rate mm. per Min.	Q_{10} Compared with Rate for 6 Degrees	Q_{10} Rates Compared Progressively	Temp. Range
6	1.38	-----		
8	1.53	1.67	1.67	[illegible]
9	1.42	1.08	[illegible]	8 - 10
10	1.84	2.05		
11	1.57	1.29	3.13	[illegible]
12	1.53	1.19		
13	[illegible]	2.46		
14	2.73	2.89		
15	2.74	2.14	5.30	13 - 16
16	4.30	3.12		
17	4.82	3.18		
18	5.11	[illegible]	1.43	[illegible]
19	[illegible]	3.11		
20	4.26	2.29		
21	5.51	2.52	5.74	[illegible]
22	8.09	3.02		
23	6.17	2.41		
24	6.04	2.31		
25	8.77	2.65	1.31	[illegible] - 25
26	5.17	1.93		
27	4.36	1.69		
28	5.51	1.88		
29	5.22	1.98	[illegible]	[illegible]
30	6.20	1.87		
32	4.40	1.56		

In the second last column of Table XX are given the values of Q_{10}, calculated according to the more usual procedure of comparing the rates progressively, and in the last column, the temperature interval for which these values were calculated. We have omitted in this progression those rates which were smaller at a higher than those at a preceding lower temperature, so as to avoid the use of fractional coefficients.

It will be evident from Column 3 of this table, that the value of Q_{10} is not constant. It varies between 1.[illegible] and 3.18. It seems to vary in three stages. Between 6 and 12, its value is very close to 1.5; between 12 and 25 degrees, it is very close to 2.7 and between 25 and 32 degrees, it is very close to 1.8. The suggestion might easily be elaborated that we are, therefore, dealing with a progressive change in the organism itself, and that whatever the factors are that condition the rate of locomotion, they are variously operative at different stages in the temperature range. -- We shall return to this point in our discussion.

It is also evident from the table that there is a very marked diminution of the coefficient above 25 degrees. In discussing the temperature coefficient of biological processes in general, we have called attention to the fact that it is rather common to find such a decrease in the value of the coefficient in all those processes that exhibit an optimum. Just what the meaning of this phenomenon is in the present case cannot, of course, be definitely stated, but that it is a common characteristic of vital processes is obvious.

In Column 4 of Table XX, as we have said, are given the temperature coefficients of the rates for rising temperatures, calculated by comparing the rates progressively. In other words, the rate, k_2 of one calculation, becomes k_1 for the next, while t_2 of one becomes t_1 for the next. This column is inserted here only because this is the more common method of calculating the

coefficient. Clearly, the value of Q_{10} in this column is not such as to give us a better insight into the relation of temperature to the rate of locomotion.

D. The Temperature Coefficient of the Average Rate for Five Degree Intervals

We have seen from Table XVII that there is a progressive increase in the rate of locomotion in Amoeba for five degree intervals from 10 to 25 degrees and then a decrease in the rate. The temperature coefficients for these changes are given in Table XXI. The table is arranged like the preceding one, with the difference, however, that in the third column, the coefficients are calculated with the rate at 10 degrees for comparison. The same general features of locomotor behavior are shown in this table as are shown in the previous one. The rapid increase in rate at the lower temperatures, and the gradual decline in rate after the optimum has been reached, are emphasized better perhaps in this table than in the preceding one.

The variations in the value of Q_{10} are plotted in Fig. 18, together with the variations in the rate of locomotion, -- thus better to show the relation between the values of the rates and those of Q_{10}.

TABLE XXI

THE VALUE OF Q_{10}.

For Five Degree Intervals
(Calculated from the Whole Mass of Data)

Temperature Degrees C	Rate Mm. per Min.	Q_{10} Compared with Rate for 10 degrees	Q_{10} Rates Compared Progressively	Temp. Range Degrees C
10	1.5	----	----	
15	3.5	5.42	5.42	10 - 15
20	4.9	3.27	1.96	15 - 20
25	5.5	2.38	1.26	20 - 25
30	5.4	1.89	-1.530*	25 - 30

*Calculated by taking K_2 for 25 degrees and K_1 for 30 degrees (Snyder's method).

[illegible]. The Temperature Coefficient of Maximal Rates

It will be recalled from a previous part of this paper, that the maximal rate which an amoeba may attain at a given temperature, seems to be definitely determinable by that temperature. We have shown that these maximal rates increase from [illegible].8 mm. per minute at [illegible] degrees to a rate of 1[illegible].5 mm. per minute at [illegible]1.5 degrees, and that beyond this optimum there is a fairly sharp decline in the maximum attainable rate. The maximal values at various temperatures have been given in Table XVIII, but they are repeated in Table [illegible], where also the values of Q_{10} are given for these rates. The coefficients are all calculated by comparing the rates at the higher temperatures with the rate at [illegible] degrees. The values of the coefficient are plotted in Fig. 19.

The uniformity of the temperature coefficient of the maximal rates is striking, especially when this uniformity is compared with the great variability of the coefficient of average rates, which we have had such frequent occasion to point out. Over a ten degree range, from 15 to approximately 25 degrees, the value of the coefficient is practically constant. The value of the coefficient below 10 degrees again emphasizes the relatively greater value of the coefficient at lower than at higher temperatures, and its value below [illegible]1.5 degrees, the relatively smaller value at higher than at lower temperature. While in general, therefore, the values of the temperature coefficient for maximal rates varies in the same sense as that for average rates, still, Q_{10} for maximal rates is much more constant.

Another point that may be noteworthy is the following. The maximum average rate, as we have seen, lies very near 2[illegible] degrees. The

greatest maximum rate on the other hand is at 21.5 degrees. There is, therefore, a shift downward in the greatest value of at least a degree and a half for the maxima as compared with the average values. Whether or not this is significant cannot be said without further investigation.

T A B L E XII

THE VALUE OF Q_{10} for Maximal Rates at Various Temperatures

Temperature Degrees C	Rate Mm. per Min.	Q_{10} Compared with Rate at 6 degrees
6	2.8	----
10	4.5	3.27
15	6.7	2.64
18	8.9	2.62
20	10.7	2.61
21.5	12.5	2.63
24	11.2	2.16
27	11.0	1.92
28	9.0	1.70
30	6.5	1.42

F. Summary of Results from the Various Calculations of the Value of Q_{10}

The various calculations of the value of Q_{10} have each revealed some special features of the dependence of locomotor activity on temperature.

1. The comparison of the values of Q_{10} for the immediate response to a change of temperature has emphasized,

    a) the great variability in the value of the coefficient;

    b) the existence of abnormally large coefficients at, what are presumably, critical points in locomotor behavior.

2. The comparison of the values of Q_{10} for the average rates of an individual at different constant temperatures has emphasized,

    a) the large preponderance of coefficients that lie between 1.5 and 5.5;

    b) the occasional occurrence of comparatively large coefficients between small temperature intervals.

3. The comparison of the values of Q_{10} for the average rates of different individuals at different temperatures has emphasized

    a) the three temperature stages in the variations of the value of the coefficient;

    b) the marked decrease in the value of the coefficient above 25 degrees.

4. Q_{10} for five degree intervals calculated from the whole mass of data, has emphasized,

    a) the high value of the coefficient at the low temperatures;

    b) the gradual decrease in its value as the optimum is gradually approached and finally passed.

5. Q_{10} for maximal rates has emphasized,

    a) the constancy of this coefficient over a comparatively large temperature range;

    b) the three temperature stages in the value of this coefficient, already referred to under 3, a) above.

3. A DISCUSSION OF THE MEANING OF THE FLUCTUATIONS IN VALUE OF Q_{10} FOR THE RATE OF LOCOMOTION

The following outstanding characteristics of the temperature coefficient for the rate of locomotion in Amoeba demand further discussion:

1) The extremely great variation in the value of the coefficient for the temperature changes to which a single individual was subjected.

2) The relatively high value of the temperature coefficient at the lower temperatures.

3) The decreasing value of the coefficient in the higher temperatures.

A. Variation in the Value of Q_{10}.

In Table XIX, we have summarized some of the data presented in extenso in Table XV, together with the temperature coefficients for the various changes in temperature to which the different individuals were subjected. We have seen that the value of the temperature coefficient for average rates of different individuals may vary between 1.0 and 16, an extremely great variation.

This fact must clearly be correlated with a number of others which have been touched upon in the preceding pages.

a) the great variations in the average values of the rate of locomotion at constant temperature; and

b) the influence of rhythm upon the rate of locomotion.

We have emphasized the fact that the rate of locomotion is determined to no small extent by the phase of both the long-period and the short-period rhythm, in which the amoeba happens to be at the moment when the measurements are made.

It is clear, therefore, that if these observations are correct, the rhythm must influence the value of the coefficient. Lorande L. Woodruff ('11a) has shown that in his pedigreed cultures of Paramecium "the reproductive activity shows cycles and rhythms". These cycles and rhythms are of much longer duration than those we have found in the study of the rate of locomotion. Still, in some respects, they may be comparable. In his studies on the temperature coefficient of the rate of reproduction of this organism, Woodruff found that "a series of a line of cells with the descending phase of the rhythm predominant, subjected to 28 degrees, and a line of cells with the ascending phase predominant, subjected to 24.5 degrees, may actually show (during the persistance of the rhythms) a more rapid rate of division at the lower than at the higher temperature. Accordingly, in this study it has been necessary to be sure that the animals subjected to the different temperatures were in comparable phases of the rhythm, or that the experiments were sufficiently prolonged to include one or more complete rhythms. It is clear that rhythms are a factor which must be taken into account in any study of the physiology of this animal." (pg. 149).

Woodruff's is perhaps the most striking investigation of such a phenomenon in protozoa which has been found in the literature, and it is of such convincing a character that there can be no doubt that his caution regarding "comparable phases of the rhythm" must be applicable also in the present work. Unfortunately, however, observational difficulties make it very difficult to discover the exact quantitative relations between the periods and the cycles, -- what we have called, short-period and long-period rhythms -- in Amoeba. The long-period rhythm in Amoeba is approximately an hour's length in duration, and as its discovery means continued observation under controlled temperature conditions, as we have stated, it is not surprising that all the individuals studied were not

"in comparable phases of their long-period rhythm. Regarding the short-period rhythm, the effects of this are probably effaced after a comparatively short period of observation, in some cases, perhaps, after ten minutes, or even less. Now, when it is borne in mind that in Table XV , averages for observations of decidedly varying duration were presented, and that no uniformity in the duration of our observations could be secured, owing to our experimental methods, it is not at all surprising that the temperature coefficients should show so wide a divergence.

We may, therefore, conclude with some assurance;

(1) If the rates of all the individuals studied in this investigation had been measured "at comparable phases of their rhythm", the values of the temperature coefficient would probably have been much more uniform.

(2) Fluctuations in the value of the temperature coefficients for different amoebae are probably due to a great extent to the fact that all amoebae cannot well be studied when they are in such "comparable phases of their rhythm".

B. The High Value of Q_{10} at Low Temperatures -

A second point regarding the temperature coefficient which needs further discussion is its relatively high value at low temperatures. We have seen that in the case of one individual, XXXIX, the value of this coefficient was [illegible]*, and in another case, that of individual XXXV, it was even greater. We have also pointed out the fact that for the general average rates the value of Q_{10} between 10 and 15 degrees is [illegible], -- a much higher value than it has at higher temperatures.

The point is a very obscure one, but nevertheless the suggestion might be made that we are here dealing with a phenomenon in some way related to the heat of imbibition of colloidal substances.

a) Several workers on Amoeba in this laboratory have commented upon a very noticeable, apparent, reduction in volume of Amoeba under certain conditions. It is certain that when Amoeba comes to rest in low temperatures, there is sometimes an extreme diminution in the area visible in any one optical plane under the microscope. Whether or not, this reduction in the "optical area" is associated with a reduction in volume, cannot be definitely stated. It seems likely, however, that there is such a reduction. If there is, the reduction is conceivable only as an extrusion of water.

b) Livingston ('03) has shown that "If a filament of any common alga be carefully dried externally and placed in olive oil, whose temperature is then rapidly lowered to the vicinity of 0 degrees C., a film of water may be seen to form around the filament, and partial plasmolysis may be observed. When the temperature is again brought back to normal, the extruded water is again absorbed.

*[illegible]

The same phenomenon may be produced in Spirogyra and in Stentor coeruleus and the process in both of these forms is reversible. Lepeschkin, Greeley, ('01, '02, '03, '04) describes the changes that take place in protozoa when the temperature is lowered; and maintains that these changes are accompanied by a loss of water.

c) Furthermore, Zsigmondy ('20, pp. 265-70), quoting the results of Wiedemann and Lüdeking ('85), says that the heat of imbibition per gram of gelatine is 5.7 calories. Now, if it could be shown that this heat imbibition is related in some way to the amount of water already present, in the imbibing substance, we should have a possible explanation of the magnitude of the temperature coefficient at these low temperatures. Rodewald ('97) quoted by Zsigmondy has shown that the heat of imbibition of water by starch is determined by the quantity of water already present. This fact becomes evident from the following table, in which, in the first column are given the percentage of water already present in the imbibing substance, and in the second, the number of calories developed by imbibition, per gram of imbibing substance.

% of Water Present in Starch	No. of Calories Developed by Imbibition
0.23	28.11
[illegible]	[illegible]
8.16	12.43
12.97	7.37
19.52	2.91

More recently, Rosenbohm ('19, p. 194) concludes from his studies on the heat of imbibition: "Die Quellung von Stoffen die sich wie Gelatine verhalten, (scheinen sich) in zwei verschiedene Vorgänge zu zerlegen. Der erste Vorgang besteht in einer geringen Wasseraufnahme und in einer damit verbundenen starken positiven Wärmetönung. Daran schliesst sich die eigentliche Quellung, für die eine sehr grosse Wasseraufnahme ohne merkliche Wärmeentwicklung charakteristisch ist." Katz ('17, p. 3) is inclined to

generalize from a similar phenomenon which he found in a number of substances. "Auffällig gross ist die erste Quellungswärme aller dieser Stoffe.....die Wärmeentwicklung die auftritt, wenn eine sehr grosse Menge trockener Substanz ein Gram Wasser aufnimmt." He finds the heat of imbibition to be for

Casein..............	[illegible]	calories,
Nuclein.............	[illegible]	"
Cellulose.........	[illegible]	"
Inulin..............	[illegible]	"

Hofmeister ('90) and Pauli ('97) had stated previously that the imbibition of water by gelatine takes place at first "with a rush" and is then gradually retarded. We see then that the first amount of water imbibed gives rise to a great heat of imbibition.

Supposing, then, that Amoeba contain a minimum of water when at rest in a very low temperature, and but slightly more when it is just able to move, then a slight rise in temperature may initiate rapid imbibition. The heat of imbibition may then give rise to an internal temperature in the organism, somewhat higher than the environment. The rate of locomotion may then be determined, not so much by the temperature of the environment as by the internal temperature of the organism. [illegible], however, as the rate of imbibition retards, the internal temperature approximates more closely to the temperature of the environment, and the latter, therefore, exerts its full influence upon the rate of locomotion.

We should expect, if this is true, that the temperature coefficient should show a marked rise, at first, and then, when the processes of imbibition and water output are in equilibrium, that the coefficient should show a uniform value. The extent to which this tentative hypothesis is verifiable in the present investigation is obvious, not so much from the

temperature coefficients for average rates, which, as we have said, are influenced markedly by the [illegible], but more or less the values of the coefficients for the maximal rates. For the water content of the amoeba is probably associated in some way with plasticity, viscosity, and similar factors and these in turn determine the maximal rate. Also, the coefficient for maximal rates (see Table XXII) is rather high for the temperature interval between 0 and 10 degrees, and then becomes more uniform for a 14 degree interval.

This explanation is offered, of course, merely by way of a suggestion. The varying values of the temperature coefficient themselves would lead one to believe that we are here dealing with the resultant of a large number of factors and it is highly improbable that so comparatively simple a relation as we have just discussed determines so complex a phenomenon as the mechanism of the changes of rate in Amoeba must be. However, this explanation probably accounts, at least in part, for the abnormally high values of the temperature coefficient observed in some cases.

C. The Decreasing Value of Q_{10} at Higher Temperatures -

It is a striking fact that in almost all the investigations on the velocity of biological processes, the value of Q_{10} has been found to decrease gradually with a rise in temperature. This decrease may be so rapid and regular, that the values of the coefficient, when plotted may lie almost on a straight line inclined at a steep angle to the line of abscissas. Krogh and Johansen found such a curve for the values of Q_{10} for the development of certain fish eggs.

Various explanations for this phenomenon have been attempted. We have already referred to Sutherland's ('08) attempt to explain this fall in the value of Q_{10} by studying the relation between the velocity of nerve conduction and the viscosity of water, both at the same temperature. We have also referred to Snyder's ('11) critical examination of this view as well as Pütter's effort to see in the downward variability of Q_{10} the operation of the "Law of Minimum."

More recently, Broemser ('21) has taken up the vexed question of the velocity of the nerve impulse at different temperatures. Various workers have found Q_{10} for this reaction to range in value from 1.4 to 3.0. Broemser, however, finds it to be as low as approximately 1.02. He finds that he can explain this low coefficient by considering the velocity of the nerve impulse as a function of the osmotic pressure and the specific gravity of the solvent in the medium. The underlying idea in all such determinations and suggestions is this, that some action other than merely a chemical one must be responsible for the low value of the coefficient, and since physical reactions have for the most part smaller temperature coefficients, a given biological reaction for which the temperature coefficient is found to be low, may be conceived as dominated by some

physical process. In these explanations, there is, it would seem, no necessity of denying the simultaneous action of chemical and physical forces, as the "Law of Minimum" would immediately become operative, and the temperature coefficient, which is experimentally determined, would really be the coefficient of the process least influenced by temperature.

DISCUSSION.

The experimental data have been discussed at the end of each part of this paper. A few words regarding the wider significance of these data may here be added.

Every physiological problem must, sooner or later, bring the investigator face to face with the question of the constitution of protoplasm. The present problem, too, raises the same question. Any further discussion of the meaning of the variability of rate, of reaction to temperature, and of Q_{10} in this particular case, must necessarily go beyond those facts of experimentation that have been presented here, and must establish some sort of coordination with other facts, or perhaps with theories. It may be of some interest to touch briefly upon some such phases of the present problem. We select for special mention these three,

(1) Surface Tension as a "Cause" of Amoeboid Movement
(2) The Optimum
(3) Rhythm

(1) Surface Tension, the "Cause" of Amoeboid Movement -

It is not our purpose here to enter into this much discussed question in any detail. Our purpose is only to emphasize again the difficulty of conceiving so complicated a process as amoeboid movement in terms of so comparatively simple a process as surface tension. D'Arcy Wentworth Thompson ('17, p. 12) gives the following list of the factors which may all be operative in changing the shape, and, therefore, directly or indirectly, in determining the rate of locomotion -- of Amoeba:

1. Cohesion.	7. Viscidity.
2. Friction.	8. Diffusion.
3. Gravity	9. Osmosis

4. Pressure of various kinds from without. 10. Chemical forces within the

5. Surface Tension. 11. Electrical forces.

6. Viscosity 12. Thermal influence.

13. Growth.

Each of these factors has a temperature coefficient of its own, each is operative in a most varied and variable substance and each probably influences the organism differently under different temperature conditions. While it is true, probably, of all biological processes, that they are influenced by all of these various factors, still it is worth emphasizing the thought, in connection with amoeboid motion, which, by so many, has been considered as being among the simplest of the manifestations of organic life. The efforts made, for example, to explain amoeboid motion by so comparatively simple a process as Surface Tension, is an instance in point. It is not denied, of course, that Surface Tension probably plays a very important part in locomotion. But to see in Surface Tension the entire solution of the question of amoeboid movement, is surely to neglect such facts as that of the rhythm which we have tried to establish here. Moreover, if Surface Tension were the determining cause of locomotion, it seems highly unlikely that we should have a Q_{10} of such great value for some temperature intervals, or that its value should change over the very great range of values which we have found for that coefficient in the present investigation.

(2) The "Optimum" -

Moreover, if we are to adopt the now current mode of thought regarding the structure of protoplasm, we are here in all likelihood dealing with the end result of a chain of enzyme actions, all operative in a heterogeneous colloidal system. Höber ('14, pg. 710) has emphasized the complexity of reactions in such systems, especially when, as must happen in Amoeba, the calatyzer is itself a colloid. For in such cases we have to take cognizance of the change in surface area (effective area) of a large number of particles, of imbibition on the part of the disperse phase, of the formation of intermediate products, and of a large number of other partial, or relative, processes, all contributing towards the end result. Höber, while granting that it has thus far not been possible to embrace all of these processes in a single formula, still hopes that light will be thrown upon all this complex physiological behavior through the study of the "anorganic ferments" of Bredig, the colloidal metals.

One of the chief difficulties against anything like a simple explanation of such processes as we are here discussing, is the occurrence of an "optimum" in many biological processes. Bayliss ('11, pg. 77) says: "The effect of heat upon the activity of enzymes holds up to a certain temperature, which varies according to conditions. Up to this point, raising the temperature increases the rate of change, but a further rise slows reaction again." We have emphasized this mode of behavior so general in biological processes in our graph for the rate of locomotion.

In his explanation of this phenomenon, Bayliss (l.c.) recalls that Ernst ('01) has demonstrated an "optimum" for the reaction of colloidal platinum upon mixture of hydrogen and oxygen gas. He parallels with this the work of Blackman ('05) on the carbon assimilation of the green

leaf, and concludes: "In the first place, the apparent optimum temperature will vary considerably according to the time which has elapsed between the beginning of the exposure to a particular temperature, and the period during which the estimation is made. Secondly, the so-called optimum temperature is merely an expression of the fact that at a certain temperature the increased velocity due to this raised temperature is more than sufficient, for the time only, to counteract the rapid destruction of the enzyme. It (the optimum) has, therefore, a negligible importance, both theoretically and practically."

It may be doubted whether this simple explanation will hold for the "optimum" of locomotor activity, in the present investigation. In the first place, the optimum, as we are here speaking of it, is the average of a large number of observations on a large number of individuals, during a prolonged time period. It is quite conceivable that an optimum in Bayliss' sense should be found for even a complicated biological process in an individual, in which it is observed for a comparatively short period of time. Moreover, Blackman establishes three facts upon which he bases his interpretation of the optimum:

First, "At high temperatures (30 degrees and above for leaves of cherry laurel) the initial rate of assimilation cannot be maintained, but falls off regularly." (Quoted from Bayliss, l.c.). This can hardly be accepted unqualifiedly for our data in the present case. Individual AAA, for example, (see Performance Record and Graph AAA) maintained its optimal average rate at [illegible] for 16 minutes at [illegible] degrees, a temperature only half a degree removed from the optimal average rate as calculated from the whole mass of data. Moreover, and this strengthens the argument, the maximal rate of movement during a single minute, was attained, not immediately after the temperature was changed, but fully

ten minutes after the change. The oscillations in rate at this temperature were no greater at 33 degrees than they were in any other temperature. Rates per minute in a supra-optimal temperature may actually occasionally show this type of optimum described by Blackman, but average optimal rates certainly do not.

Bayliss quotes Blackman's second fact, upon which he bases his concept of the optimum, as follows: "The higher the temperature, the more rapid is the rate of falling off." Translating this freely into the terms of our series of experiments, it should mean, that the higher the temperature is above the optimum, the less time should elapse before the rate should decline. Individual XXII (See Performance Record and Graph XXII) was kept at a temperature of 25 degrees, a full degree above the optimum, for 55 minutes. During that time, it maintained an average rate of 11.08 mm. per minute. Its maximum rate per minute was 20 mm. per minute. It attained this shortly after the temperature had been raised from 22 degrees, and in so far it acted in accord with Blackman's generalization, but it also again attained that rate AFTER IT HAD BEEN IN THE SUPRA-OPTIMAL TEMPERATURE for 50 minutes. In fact, the average rate of locomotion for, say, a ten minute interval, was higher at about the middle of its persistence in the supra-optimal temperature than it had been in the beginning. Similarly, Individual LVI reached its maximum rate 10 minutes after it had been exposed to 26 degrees, and 20 minutes after it had been exposed to 27.5 degrees. Individual XXIII (See Performance Record and Graph XXIII) reached its maximum rate at 28 degrees, several degrees above the optimum, therefore, after 30 minutes exposure to this high temperature.

The third fact upon which Blackman bases his interpretation of the optimum is thus quoted by Bayliss: "The falling off at any given temperature

is fastest at first and subsequently becomes less rapid." He argues from this that it is "impossible to determine the highest value at any given temperature, since it is obviously necessary to allow the reaction to continue for a certain time." In our present case, allowing the exposure to continue for a certain time seems the only adequate manner of arriving at the highest rate, -- unless, of course, the temperature should be harmful. This is true, because, as we have said repeatedly, the rhythmic activity may otherwise obscure the effect of exposure to the new temperature.

From all of this, we may well conclude that we are here dealing with another kind of "optimum" than the one described by Blackman. This particular matter was not kept in mind in the study of the graphs, and it is possible that some striking corroborations of Blackman's views may have escaped notice. Still, it seems possible that Bayliss' analogy between the optimum of a physiological reaction, and the optimum of the action of colloidal platinum on a mixture of oxygen and hydrogen gas, may not be extendible to cases such as ours. The explanation of this may well lie in the fact which we have already emphasized in the introduction, that we are here dealing not with a primary, but with a secondary physiological process.

(3) Rhythm -

Höber ('11, pg. 753) discusses the possibility of accounting for rhythm in organisms by a process of periodic catalysis. He instances the investigations of Bredig and Weinmayr ('03), Bredig and Wilke ('04) and Bredig ('07) on the periodical escape of oxygen from the contact surface of mercury and slightly alkaline hydrogen peroxide. The evolution of oxygen from such a surface, it seems, may continue for hours, the bubbles of oxygen escaping with great regularity. Höber tells us that this process "(kann) vielleicht als ein Modell für einen enzymatischen Prozess in einem heterogenen System von der eben erwähnten für die Zelle angenommen Art aufgefasst werden." The process, it would seem, may be influenced by external factors, such as temperature, acids, alkalis, salts, alcohol, etc. The analogy is, of course, an extremely interesting one, but it is easy, it would seem, to point out great differences between it and such rhythmic activity as we have described in the locomotor processes in Amoeba. The rhythm in this chemical reaction, according to the figures and graphs given by Höber, is absolutely regular. There is no evidence of regulation. It shows none of those momentary differences of character that are so characteristic of the behavior of the organism we are studying. It cannot simulate, such a condition, for example, as an increased rhythmic activity after a period of rest. In general, we should say, that this analogy of "chemical behavior", has about the same value as many others of such simulations of organic processes by inorganic agencies. They are admittedly analogies.

The subject of rhythm is still one of the open questions in biology. Its general interpretation as the manifestation of reversible chemical processes which take place in the cell, probably leaves much to be desired, though undoubtedly it is close to the truth.

SUMMARY AND CONCLUSIONS.

Conclusions and deductions have been stated at the close of each section of this paper. The outstanding features of locomotor behavior of Amoeba, in its relation to temperature, which have been found in this investigation, might be summarized and grouped as follows:

A. Locomotor Behavior of Amoeba at Constant Temperature

1. Amoeba, at constant temperature, shows decided variations in the rate of its locomotor activity. There is no fixed rate at which an animal must move at a given temperature. There seems to be, however, a maximum rate which cannot be exceeded at that particular temperature.

2. This limitation of the rate of movement by temperature is interpretable as a change in the physical or chemical characteristics of the protoplasm, which, at higher temperatures, enables the protoplasm to "flow" with less friction. Beyond a certain point of temperature, however, a reverse change occurs, which again retards the rate of movement.

3. The variations in the rate of movement, however, are ascertainably, the expression of the rhythmic character of the processes which condition locomotion.

4. This rhythm is manifested by a succession of alternately accelerated and retarded rates of movement. These accelerated and retarded phases are coincident with eruptive and refractory activity in the organism.

5. The relation of rates during these two phases of rhythmic activity is numerically expressible by a Ratio of Rates, the value of which remains comparatively constant, sometimes for rather prolonged time periods.

6. The rhythm, even at constant temperatures, may be altered, that is, it may be "pitched at a higher or lower scale". When this happens, the ratio of rates may still remain of the same value which it had before the change.

7. Variations in the value of the ratio of rates do, however, occur. This may be due to the fact that the measurements are taken by an observer, at instances when the same individual or various individuals are not "in comparable phases" of a long-period rhythm. Indications for the existence of such a long-period rhythm, though by no means conclusive, are not entirely wanting.

B. Rates of Locomotion at Different Temperatures.

8. The response of Amoeba to both falling and rising temperatures is extremely varied, both qualitatively and quantitatively.

9. This great difference in the character of the response may, possibly, be due to the particular phase of rhythmic activity at the instant when the temperature change exerts its influence.

10. When average rates at different temperatures for the same and for different individuals are compared, however, there is in general an increase of rate with increasing and a decrease of rate with decreasing temperature.

11. This holds true within a range of temperatures that lie, approximately, between 6 and 25 degrees. Near the latter temperature, an optimal rate is reached.

12. When the temperature is raised above this optimum, the rate of locomotion decreases.

13. When the temperature is changed, the short-period rhythm is "pitched" on a higher or a lower level.

14. The long-period rhythm, on the other hand, tends to be obliterated, if the change of temperature is great enough.

C. The Measure of the Dependence of Locomotion upon Temperature

15. The value of Q_{10} for the rates of locomotion of an individual at different temperatures is extremely varied.

16. The value of Q_{10} for comparatively slight changes of temperature from a low level, near 10 degrees, when the Amoeba is barely able to move, to one slightly higher, is enormous. This probably indicates the existence of a physiological critical point.

17. The value of Q_{10} is neither as constant as it is for some physiological processes nor is it more variable that it has been found to be for others.

18. The value of Q_{10} for averages of five-degree temperature intervals in the whole mass of data, ranges between 5.4 for the interval 5-10 degrees and 1.9 for the interval 25-30 degrees, giving a decreasing value for the higher temperatures.

BIBLIOGRAPHY.

Many of the investigations mentioned in the preceding pages were not cited from the original publications but from summaries. For the sake of completeness, however, they are included in this bibliography. The sources of the citations are indicated by capital letters and these are followed by page references. These letters, with the works to which they refer, are :

K = Kanitz, Temperatur und Lebensvorgänge.

B = Bayliss, The Nature of Enzyme Action.

H = Höber, Physikalische Chemie der Zelle und der Gewebe.

D = Davenport, Experimental Morphology.

Z = Zsigmondy, Kolloidchemie.

Abegg, R. 1905. Der Temperatureinfluss auf die Entwicklungsgeschwindigkeit animalischen Lebens. Zeitschr. f. Elektrochemie, XI, 528.

Aberson, J.H. 1903. La Fermentation Alcoolique. Rec. Trav. Chim. Pays-Bas, XXII, 78 (K., p. 15).

Arrhenius, Svante. 1889. Über die Reaktionsgeschwindigkeit bei der Inversion von Rohrzucker durch Säuren. Zeitschr. f. Physik. Chem. IV, 226 (K., p. 9).

Arrhenius, Svante. 1915. Quantitative Laws in Biological Chemistry. London. Bell.

Bayliss, W.M. 1911. The Nature of Enzyme Action. London. Longmans.

Berthelot, M. 1862. Essai d'une Theorie sur la Formation des Ethers. Ann. de Chimie et de Phys. LXVI, 110 (K., p. 2).

Blackman, F.F. 1905. Optima and Limiting Factors. Ann. of Botany, XIX, 218 (F., pp. 77, 122).

Blackman, F.F. 1908. The Manifestation of the Principles of Chemical Mechanics in the Living Plant. Address, Section K, B.A.A.S. Nature, LXXVIII, 556. Amer. Natur. XLII, 632 (K., p. [illegible]).

Bodenstein, Max. 1913. Eine Theorie der photochemischen Reaktionsgeschwindigkeit. Zeitschr. f. Physik. Chem. LXXXV, [illegible] (K., p. 11).

Borowsky, Wladimir. 1910. Untersuchungen über Actinosphaerium Eichhorni. Arch. f. Protistk. XIX, 255 (K., p. 130).

Bredig, G. 1907. Biochem. Zeitschr. VI, 283 (H., p. 738).

Bredig, G. u. Weinmayer, J. 1903. Eine periodische Kontaktkatalyse. Zeitschr. f. Physik. Chem. XLII, 602 (H., p. 738).

Bredig, G. und Wilke. 1904. Verhandl. d. naturhist.-mediz. Vereins zu Heidelberg. N.F. VIII, 165 (H., p. 738).

Broemser, Ph. 1921. Nervenleitungsgeschwindigkeit und Temperatur. Zeitschr. f. Biologie, LXXIII, 19.

Brunner, Erich. 1904. Reaktionsgeschwindigkeit in heterogenen Systemen. Zeitschr. f. Physik. Chem. XLVII, 56 (K., p. 11).

Burian, R. Die Exkretion. Winterstein,

Clausen, H. 1890. Beiträge zur Kenntniss der Atmung der Gewächse und des pflanzlichen Stoffwechsels. Landw. Jahrb. XIX, 893 (K., p. 14).

Davenport, Charles B. 1908. Experimental Morphology. New York. MacMillan.

Davis, P.B. and Jones, Harry C. 1912. Leitfähigkeits- und negative Viskositätskoeffizienten gewisser Rubidium- und Ammoniumsalze in Glyzerin und in Gemischen von Glyzerin mit Wasser, von 25 bis 75 Grad. Zeitschr. f. Physik. Chem. LXXXI, 68 (K., p. 166).

Dellinger, Orris P. 1906. Locomotion in Amoebae and Allied Forms. Jour. Exp. Zool. III, 337.

Doflein, F. 1916. Lehrbuch der Protozoenkunde. Jena. Fischer.

Ernst, C. 1901. Über die Katalyse des Knallgases durch kolloidales Platin. Zeitschr. f. Physiol. Chem. LI, 448 (K., pp. 77, 124).

Greeley, Arthur W. 1904. Experiments on the Physical Structure of the Protoplasm of Paramoecium and Its Relation to the Reactions of the Organism to Thermal, Chemical and Electrical Stimuli. Biol. Bull. VII, 3.

Grosse-Allermann, Wilhelm. 1909. Studien über Amoeba Terricola. Arch. f. Protistenk. XVII, 201.

Gruber, Karl. 1912. Biologische und Experimentelle Untersuchungen an Amoeba Proteus. Arch. f. Protistk. XXV, 316.

Halban, Hans von und Kirsch, Alexander. 1913. Über die Xanthogensäure und die Kinetik ihres Zerfalls. Zeitschr. f. Physik. Chem. LXXVII, 253 (K., p. 8).

Harcourt, A. Vernon. 1867. On the Observation of the Course of Chemical Change. Jour. Chem. Soc. XX (N.S. V) 462 (K., p. 9).

Harcourt, A. Vernon. 1912. On the Variation with Temperature of the Rate of a Chemical Change. Transact. Roy. Soc. CCXII, 187 (K., p. 9).

Harcourt, A. Vernon and Esson, William. 1895. On the Laws of Connexion between the Conditions of a Chemical Change and Its Amount. III. Trans. Roy. Soc. CLXXXVI, 828 (K., p. 8).

Hecht, Wilhelm und Conrad, M. 1889. Beiträge zur Bestimmung von Affinitätskoeffizienten. Zeitschr. f. Physik. Chem. III, 468 (K., p. 9).

Hertwig, Oscar. 1898. Über den Einfluss der Temperatur auf die Entwicklung von Rana fusca und Rana esculenta. Arch. f. mikr. Anat. LI, 319 (K., p. 11).

Hill, A.V. 1913. The Energy Degraded in the Recovery Process of Stimulated Muscles. Jour. Physiol. XLVI, 28.

Höber, Rudolf. 1914. Physikalische Chemie der Zelle und der Gewebe. Berlin. Engelmann.

Hofmeister, F. 1890. Arch. f. Exper. Pathol. u. Pharmak. XXVII, 395 (K., p. 378).

Jollos, Victor. 1913. Experimentelle Untersuchungen an Infusorien. Biol. Centrbl. XXXIII, 222.

Kanitz, Aristides. 1905. Über den Einfluss der Temperatur auf die Kohlendioxydassimilation. Zeitschr. f. Elektrochem. XI, 689 (K., p. 16).

Kanitz, Aristides. 1907. Über den Einfluss der Temperatur auf die pulsierenden Vakuolen der Infusorien und die Abhängigkeit biologischer Vorgänge von der Temperatur überhaupt. Biol. Centrbl. XXVII, 11 (K., pp. 16, 62).

Kanitz, Aristides. 1915. Temperatur und Lebensvorgänge. Berlin. Gebrüder Borntraeger.

Khainsky, A. 1910. Zur Morphologie und Physiologie einiger Infusorien (Paramaecium caudatum) auf Grund einer neuen histologischen Methode. Arch. f. Protistk. XXI, 26 (K., p. 62).

Krogh, A. and Johansen, A.C. 1914. The Influence of Temperature and Certain Other Factors upon the Rate of Development of the Eggs of Fishes. Conseil Internat. pour l'Explor. de la Mer. (K., p. 110).

Livingstone, Burton E. 1903. The Rôle of Diffusion and Osmotic Pressure in Plants. Chicago. Univ. of Chicago Press.

Loeb, Jacques. 1905. On Chemical Methods by which the Eggs of a Mollusc (Lottia gigantea) Can Become Mature. Univ. Calif. Publ. III, 1 (K., p. 16).

Loeb, Jacques. 1906. The Dynamics of Living Matter. New York. Macmillan.

Matisse, Georges. 1919. Action de la Chaleur et du Froid sur l'Activite Motrice des Etres Vivants. Paris. Larose.

Maltaux & Massart. 1906. Recueil de l'Institute Botanique de Bruxelles. VI (K., p. 123).

Moore, A.R. 1910. The Temperature Coefficient of the Duration of Life in Tubularia Crocea. Arch. f. Entw.-Mech. XXIX, 287 (K., p. 107).

Nernst, W. 1904. Theorie der Reaktionsgeschwindigkeit in heterogenen Systemen. Zeitschr. f. Physik. Chem. XLVII, 52 (K., p. 11).

Noyes, A.A.

Ostermann, Giuseppina. 1904. Richerche fisiologiche e tossicologiche sulle Vorticelle. Arch. di Fisiol. I, 1 (K., p. 62).

Ostwald, Wilhelm. 1887. Lehrbuch der allgemeinen Chemie. 1st Ed. Leipzig.

Ostwald, Wilhelm. 1900. Grundlinien der anorganischen Chemie. 1st Ed. Leipzig.

Peter, Karl. 1905. Der Grad der Beschleunigung tierischer Entwicklung durch erhohte Temperatur. Arch. f. Entw.-Mech. XX, 130 (K., p. 10).

Plotnikow, Johannes. 1912. Photochemische Studien. Über den photochemischen Temperaturkoeffizienten von Brom. Zeitschr. f. Physik. Chem. LXXVIII, 573 (K., p. 11).

Pütter, August. 1911. Vergleichende Physiologie. Jena. Fischer.

Rautmann, H. 1909. Der Einfluss der Temperatur auf das Grössenverhältnis des Protoplasmakörpers zum Kern. Arch. f. Zellforsch. III, 44 (K., p. 130).

Rhumbler, Ludwig. 1898. Physikalische Analyse von Lebenserscheinungen der Zelle. Arch. f. Entw.-Mech. VII, 103.

Rodewald, H. 1897. Thermodynamik der Quellung mit spezieller Anwendung auf die Stärke und deren Molekulargewichtsbestimmung. Zeitschr. f. Physik. Chem. XXIV, 193.

Rogers, Charles G. and Lewis, Elsie, M. 1914. The Relation of the Body Temperature of the Earthworm to that of Its Environment. Biol. Bull. XXVII, 262.

Rossbach, M.J. 1872. Die rhythmischen Bewegungserscheinungen der einfachsten Organismen und ihr Verhalten gegen physikalische Agentien und Arzneimittel. Verh. Phys.-Med. Ges. Würzburg. I, 179; Arbeiten a. d. Zool.-Zoot. Inst. Würzburg. I, 9 (D., pp. 57, 213).

Schaeffer, Asa A. 1916. Notes on the Specific and Other Characters of Amoeba Proteus Pallas (Leidy), A. Discoides spec. nov., and A. Dubia spec. nov. Arch. f. Protistk. XXXVII, 204.

Schaeffer, Asa A. 1920. Ameboid Movement. Princeton. Princeton Univ. Press.

Schurmayer, C.B. 1890. Über den Einfluss äusserer Agentien auf einzellige Wesen. Jena. Zeitschr. XXIV, 402 (D., pp. 271, 285).

Shelford, V.E. and Allee, W.C. 1913. The Reactions of Fishes to Gradients of Dissolved Atmospheric Gases. Jour. Exper. Zool. XIV, 207.

Snyder, Charles D. 1905. On the Influence of Temperature upon Cardiac Contraction and Its Relation to Influence of Temperature upon Chemical Reaction Velocity. Univ. Calif. Publ., Physiology, II, 125 (K., p. 16).

Snyder, Charles D. 1908 a. The Temperature Coefficient of the Velocity of Nerve Conduction. Amer. Jour. Physiol. XXII, 179.

Snyder, Charles, D. 1908 b. A Comparative Study of the Temperature Coefficients of the Velocities of Various Physiological Actions. Amer. Jour. Physiol. XXII, 309.

Snyder, Charles D. 1911. On the Meaning of Variation in the Magnitude of Temperature Coefficients of Physiological Processes. Amer. Jour. Physiol. XXVIII, 167.

Snyder, Charles D. and Todd, Martillus H. The Viscosity of Body Fluids at Various Temperatures within Physiological Limits. Amer. Jour. Physiol. XXVIII, 161.

Stempell, Walter and Koch, Albert. 1916. Elemente der Tierphysiologie. Jena. Fischer.

Theodor, Paul; Birstein, Gustav and Reuss, Anton. 1910. Beitrag zur Kinetik der Giftwirkung von gelösten Stoffen II. Biochem. Zeitschr. XXIX, 267 (K., p. 96).

Thompson, D'Arcy Wentworth. 1917. Growth and Form. Cambridge. Univ. Press.

Van't Hoff, J.H. 1884. Études de dynamique chimique. Amsterdam.

Weigert, Fritz and Kruger, Otto. 1913. Über umkehrbare photochemische Reaktionen im homogenen System. Zeitschr. f. Physik. Chem. LXXXV, 629 (K., p. 11).

Wiedemann, E. and Lüdeking, Ch. 1885. Wiedmanns Annalen d. Phys. u. Chem. N.F. XXV, 145 (K., p. 370).

Wilhelmy, Ludwig. 1850. Über das Gesetz nach welchem die Einwirkung der Säuren auf den Rohrzucker stattfindet. Poggen. Ann. LXXXI, 413 (K., p. 2).

Woodruff, Lorande, L. 1917. The Influence of General Environmental Conditions on the Periodicity of Endomixis in Paramecium Aurelia. Biol. Bull. XXXIII, 437.

Woodruff, L.L. and Baitsell, G.A. 1911 a. The Temperature Coefficient of the Rate of Reproduction of Paramecium Aurelia. Amer. Jour. Physiol. XXIX, 147.

Woodruff, Lorande L. and Baitsell, George A. 1911 b. Rhythms in the Reproductive Activity of Infusoria. Jour. Exper. Zool. XI, 339.

Zsigmondy, Richard. 1920. Kolloidchemie. Leipzig. Spamer.

Addenda.

Gibbs, David and Dellinger, O.P. 1908. The Daily Life of Amoeba Proteus. Amer. Jour. Psych. XIX.

Katz, J.R. 1917. Die Gesetze der Quellung. Koll.-Chem. Beihefte IX.

Rosenbohm, Ernst. 1914. Über die Wärmeentwicklung bei der Quellung von Kolloiden. Koll.-Chem. Beihefte VI.

VITA.

Alphonse M. Schwitalla was born in Upper Silesia, Germany, in 1882 and came to this country in 1885. He graduated from High School in 1899 in St. Louis, Missouri. After entering the Jesuit Order, he received the A.B. degree in the College of Arts, St. Louis University, St. Louis, Missouri, in 1906. The Masters Degree was conferred on him in 1907 in the Philosophical Department of the same University. From 1907 to 1910 he acted as Instructor in Chemistry at St. Xavier's College, Cincinnati, Ohio, and then continued his studies in Biology, while acting as assistant in the Department of Physiology, at the Medical School of St. Louis University during the two ensuing years. He entered the Theological Department of the same University, in 1912, was ordained priest in 1915, and finished his theological course in 1916. The years 1917-1919 he spent as Instructor in Chemistry and Biology at Rockhurst College, Kansas City, Missouri. He entered Johns Hopkins University in 1919. His principal subject was Zoology, his subordinate subjects, Plant Physiology and Physical Chemistry.

A P P E N D I X

PERFORMANCE RECORDS
and
PERFORMANCE GRAPHS

For method of recording data (see p. 30)

For method of graphic representation (see p. [illegible])

Column 1 - No. of observation

Column 2 - Time at which observation was made

Column 3 - Time interval between two successive observations

Column 4 - Corrected temperature (see p. 41)

Column 5 - Total distance traversed by amoeba *

Column 6 - Rate during time interval given in Column 3 *

Column 7 - Remarks

*Apparent values - To reduce to real values, divide by 64 - (see p. [illegible]).


I

PERFORMANCE RECORD

of

INDIVIDUAL I

No. of Observation	Time	Time Interval Min.	Temperature Degrees C	Total Distance Mm.	Rate Mm. per Min.	Remarks
1	12:18	0	9	0	0	
2	12:23	5	"	1	0.2	
3	12:28	5	"	3	0.6	
4	12:32	4	"	6.5	1.3	
5	12:33	1	"	4	4	
6	12:34	1	"	3.5	3.5	
7	12:35	1	"	3.5	3.5	
8	12:38	3	"	5	1.7	
9	12:40	2	"	3.5	1.75	
						Temp. changed, 12:40:30
10	12:41	0	Variable	0	0	
11	12:43	2	24	7	3.5	
12	12:44	1	"	18	18	
13	12:45	1	"	9	9	
14	12:47	2	"	13	6.5	
15	12:48	1	"	8	8	
16	12:50	0	Variable	0	0	No observations Temp. changed, 12:49 New record sheet
17	12:51	1	10	1	1	
18	12:55	4	"	1.5	0.38	
19	12:57	2	"	3.5	1.7	
20	12:59	2	"	2	1	
21	1:02	3	"	7	2.3	
22	1:04	2	"	3.5	1.7	
23	1:06	2	Variable	10	5	Temp. changed, 1:05
24	1:08	2	24	11	6.5	
25	1:09	1	"	10	10	
26	1:10	1	"	9.5	9.5	
27	1:12	0	Variable	0	0	Temp. changed, 1:12
28	1:16	4	10	4	1	
29	1:20	4	"	4.5	1.1	
30	1:22	2	"	2	1	
31	1:26	4	Variable	2.5	0.6	Temp. changed, 1:25

No. of Observation	Time	Time Interval Min.	Temperature Degrees C	Total Distance Mm.	Rate Mm. per Min.	Remarks
32	1:27	1	26	12	12	
33	1:28	1	"	6.5	6.5	
34	1:29	1	"	7	7	
35	1:31	2	Variable	7.5	3.7	
36	1:33	2	10	2.5	1.25	
37	1:35	2	"	5	2.5	

PERFORMANCE RECORD
of
INDIVIDUAL II

No. of Observation	Time	Time Interval Min.	Temperature Degrees C	Total Distance Mm.	Rate Mm. per Min.	Remarks
1	5:52	0	15	0	0	
2	5:53	1	"	9.5	9.5	
3	5:54	1	"	5	5	
4	5:55	1	"	5	5	
5	5:56	1	"	4.5	4.5	
6	5:57	1	"	9.5	9.5	
						Temp. changed, 5:59
7	6:00	0	10	0	0	
8	6:04	4	"	7	1.8	Interruption
9	6:08	0	"	0	0	
10	6:09	1	"	4.5	4.5	
11	6:10	1	"	4.5	4.5	
12	6:11	1	"	4	4	
13	6:12	1	"	8	8	
14	6:13	1	"	4	4	
15	6:14	1	"	6	6	
						Interruption for 45 minutes Temp. dropped to 9^{0}, 6:59 No appreciable movement up to 7:30
16	7:33	0	20	0	0	Temp. changed
17	7:34	1	"	13.5	13.5	
18	7:35	1	"	13.5	13.5	
19	7:38	3	"	18	6	
20	7:39	1	"	7	7	
21	7:40	1	"	6.5	6.5	

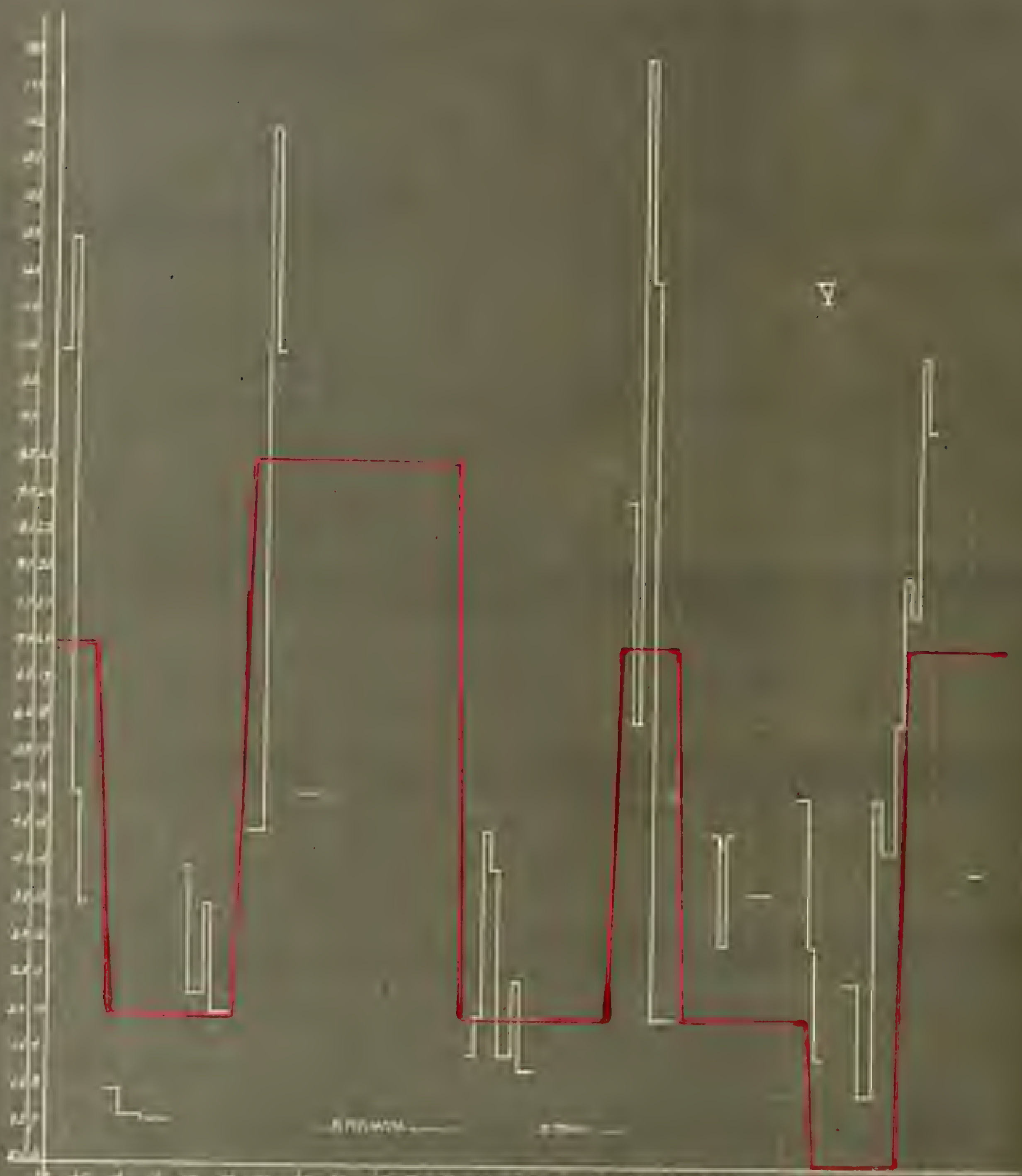

III

PERFORMANCE RECORD
of
INDIVIDUAL III

No. of Observation	Time	Time Interval Min.	Temperature Degrees C	Total Distance Mm.	Rate Mm. per Min.	Remarks
1	11:32	0	22	0	0	
2	11:34	2	"	19	9.5	
3	11:36	2	"	17	8.5	
4	11:40	4	"	35	8.8	
						Temp. changed, 11:41
5	11:42	0	10	0	0	New record sheet
6	11:43	1	"	9.5	9.5	
7	11:44	1	"	1.5	1.5	
8	11:45	1	"	1.5	1.5	
9	11:47	2	"	2	1	
10	11:49	2	"	0.75	0.37	
11	11:50	1	"	1	1	
12	11:52	2	"	1.5	0.75	
13	11:55	3	"	2	0.7	
14	11:57	0	"	0	0	New record sheet
15	12:00	3	"	1.5	0.5	
16	12:02	2	"	2	1	
17	12:07	5	"	3.5	0.7	
18	12:09	2	"	4	2	
19	12:11	2	"	4.5	2.3	
20	12:13	2	"	4	2	
21	12:15	2	"	3.5	1.75	
22	12:17	2	"	4.5	2.3	
23	12:19	2	"	6	3	
24	12:21	2	"	5.5	2.7	
25	12:23	2	"	4.5	2.3	
						Temp. changed, 12:24
26	12:25	0	Variable	0	0	
27	12:26	1	25	11.5	11.5	
28	12:28	2	"	25	12.5	
29	12:29	1	"	8	8	
						Temp. changed, 12:30
30	12:31	0	11	0	0	
31	12:32	1	"	2	2	
32	12:35	3	"	2.5	0.8	
33	12:40	5	"	2	0.4	
34	12:41	1	"	6.5	6.5	Momentary drop of temp. to 6°
35	12:45	4	"	2	0.5	
36	12:46	1	"	3	3	
37	12:47	1	"	1.5	1.5	
38	12:48	1	"	6.5	6.5	
39	12:49	1	"	4	4	
40	12:50	1	"	4	4	

III - (2)

No. of Observation	Time	Time Interval Min.	Temperature Degrees C	Total Distance Mm.	Rate Mm. per Min.	Remarks
41	12:51	0	11	0	0	New record sheet
42	12:52	1	"	5	5	
43	12:53	1	"	2.5	2.5	
44	12:54	1	"	4	4	
45	12:55	1	"	4.5	4.5	
46	12:56	1	"	6	6	
47	12:57	1	"	5.5	5.5	
48	12:58	1	"	3.5	3.5	
49	12:59	1	"	5.5	5.5	
50	1:00	1	"	9	9	
						Temp. changed, 1:00:30
51	1:01	0	Variable	0	0	New record sheet
52	1:02	1	25	3.5	3.5	
53	1:04	2	"	5.5	2.7	
54	1:06	2	"	19	9.5	
55	1:07	1	"	13.5	13.5	
56	1:08	1	"	17.5	17.5	
57	1:10	0	Variable	0	0	New record sheet Temp. changed, 1:10
58	1:28	18	11	12	0.66	
59	1:34	6	"	7	1.2	
60	1:35	1	"	5	5	
61	1:36	1	"	4.5	4.5	



V

PERFORMANCE RECORD

of

INDIVIDUAL V

No. of Observation	Time	Time Interval Min.	Temperature Degrees C	Total Distance Mm.	Rate Mm. per Min.	Remarks
1	3:01	0	20	0	0	
2	3:02	1	"	11	11	
3	3:03	1	"	12.5	12.5	
4	3:04	1	"	5	5	
5	3:05	1	"	3.5	3.5	Temp. changed, 3:06
6	3:08	0	Variable	0	0	New record sheet
7	3:10	2	10	2	1	
8	3:13	3	"	2	0.66	
9	3:17	4	"	2.5	0.62	
10	3:18	0	"	0	0	Animal changing direction
11	3:19	1	"	4	4	
12	3:21	2	"	4.5	2.3	
13	3:22	1	"	3.5	3.5	
14	3:24	2	"	4	2	
15	3:25	1	"	2	2	Temp. changed, 3:25
16	3:27	0	Variable	0	0	New record sheet
17	3:29	2	25	5	4.5	
18	3:30	1	"	14	14	
19	3:31	1	"	11	11	
						Interruption to 3:34
20	3:36	2	"	10	5	
21	3:57	0	10	0	0	Interruption to 3:57 Temp. changed, 3:55
22	3:58	1	"	1.5	1.5	
23	3:59	1	"	2	2	
24	4:00	1	"	4.5	4.5	
25	4:01	1	"	4	4	
26	4:03	2	"	3	1.5	
27	4:04	1	"	2.5	2.5	
28	4:06	2	"	2.5	1.3	
						Interruption to 4:18 Temp. changed, 4:16
29	4:18	0	20	0	0	
30	4:19	1	"	9	9	
31	4:20	1	"	6	6	
32	4:21	1	"	15	15	
33	4:22	1	"	12	12	
34	4:25	3	"	6	2	Temp. changed, 4:25

No. of Observation	Time	Time Interval Min.	Temperature Degrees C	Total Distance Mm.	Rate Mm. per Min.	Remarks
35	4:30	0	10	0	0	Interruption
36	4:31	1	"	4.5	4.5	
37	4:32	1	"	3	3	
38	4:33	1	"	4.5	4.5	Rest; began to move, 4:35
39	4:38	3	"	11	3.7	
						Interruption to 4:41
40	4:41	0	"	0	0	New record sheet
41	4:43	2	"	10	5	
						Temp. changed, 4:43
42	4:44	1	6	3	3	
43	4:45	1	"	1.5	1.5	
						Animal detached from slide
44	4:48	0	"	0	0	New starting point
45	4:49	1	"	2.5	2.5	
46	4:50	1	"	2.5	2.5	
47	4:52	2	"	2	1	
48	4:53	1	"	5	5	
49	4:55	2	"	8.5	4.3	
						Temp. changed, 4:55:30
50	4:56	1	20	6	6	
51	4:57	1	"	8	8	
52	4:58	1	"	7.5	7.5	
53	4:59	1	"	11	11	
54	5:00	1	"	10	10	No observation, 5:00 - 5:05
55	5:05	0	"	0	0	
56	5:07	2	"	8	4	

FOLD OUT

PERFORMANCE RECORD

of

INDIVIDUAL VI

No. of Observation	Time	Time Interval Min.	Temperature Degrees C	Total Distance Mm.	Rate Mm. per Min.	Remarks
1	10:27	0	20	0	0	
2	10:28	1	"	11	11	
3	10:30	2	"	11	5.5	
4	10:32	2	"	30.5	15.2	
						No observations, 10:32 - 10:51
5	10:51	0	"	0	0	New starting point
6	10:52	1	"	11	11	
7	10:53	1	"	11	11	
						No observations, 10:53 - 10:57
8	10:57	0	"	0	0	New starting point
9	10:58	1	"	11	11	Temp. changed, 10:58:30
10	11:00	2	9.5	3	1.5	Rest, one minute
11	11:05	4	"	1	0.5	
12	11:08	3	"	4	1.3	
13	11:09	1	"	2	2	
14	11:10	1	"	4	4	
15	11:11	1	"	3	3	Rest; began to move, 11:14
16	11:14	0	"	0	0	New record sheet
17	11:15	1	"	3	3	
18	11:17	2	"	4	2	
19	11:18	1	"	7	7	Pspd. active but no locomotion
						Temp. changed, 11:22
20	11:24	0	24	0	0	
21	11:25	1	"	10	10	
22	11:26	1	"	4.5	4.5	
23	11:27	1	"	10	10	
24	11:28	1	"	9	9	
25	11:29	1	"	10	10	
26	11:30	1	"	11	11	
27	11:31	1	"	8	8	
28	11:32	0	"	0	0	New record sheet
29	11:33	1	"	9	9	
30	11:34	1	"	4	4	
31	11:35	0	"	0	0	Animal changing direction
32	11:36	1	"	5	5	
33	11:37	1	"	5	5	
34	11:38	1	"	3.5	3.5	
35	11:39	1	"	10	10	
						Temp. changed, 11:40
36	11:43	0	10	0	0	
37	11:44	1	"	5	5	

No. of Observation	Time	Time Interval Min.	Temperature Degrees C	Total Distance Mm.	Rate Mm. per Min.	Remarks
38	11:45	1	10	3	3	
39	11:46	1	"	3	3	Rest; began to move, 11:47
40	11:47	0	"	0	0	New starting point
41	11:50	3	"	2	0.6	
42	11:52	2	"	2.5	1.3	
43	11:55	3	"	4	1.3	
44	11:57	2	"	4.5	2.3	
45	11:58	1	"	4	4	
46	11:59	1	"	4	4	
47	12:00	1	"	2	2	
						Temp. changed, 12:00:30
48	12:01	0	24	0	0	New record sheet
49	12:02	1	"	7	7	
50	12:03	1	"	7.5	7.5	
51	12:04	1	"	15	15	
52	12:05	1	"	12	12	
53	12:06	1	"	20	20	
54	12:07	1	"	11	11	
55	12:08	1	"	7	7	
56	12:09	1	"	10	10	
57	12:11	0	Variable	0	0	Temp. changed, 12:11
58	12:13	2	10	4	2	
59	12:17	4	"	4	1	
60	12:31	14	"	3.5	0.25	
						Temp. changed, 12:31:30
61	12:34	3	20	5	1.7	
62	12:35	1	"	4.5	4.5	
63	12:36	1	"	10	10	
64	12:37	1	"	6	6	
65	12:38	1	"	12	12	
66	12:39	1	"	14	14	
						Temp. changed, 12:40
67	12:41	0	10	0	0	New record sheet
68	12:43	2	"	8	4	
69	12:44	1	"	2.5	2.5	
70	12:46	2	"	4	2	
71	12:49	3	"	3.5	1.2	
72	12:51	0	"	0	0	Animal changing direction
73	12:53	2	"	5	2.5	
74	12:54	0	"	0	0	New record sheet
75	12:56	2	"	5	2.5	
						Temp. changed 12:57

No. of Observation	Time	Time Interval Min.	Temperature Degrees C	Total Distance Mm.	Rate Mm. per Min.	Remarks
76	12:59	0	24	0	0	Interruption to 12:59
77	1:00	1	"	5	5	
78	1:01	1	"	5	5	
79	1:02	1	"	6	6	
80	1:03	1	"	4	4	Interruption, 1:03-1:05
81	1:06	1	"	2.5	2.5	

IX

PERFORMANCE RECORD

of

INDIVIDUAL IX

No. of Observation	Time	Time Interval Min.	Temperature Degrees C	Total Distance Mm.	Rate Mm. per Min.	Remarks
1	9:25	0	18	0	0	
2	9:26	1	"	4.5	4.5	
3	9:27	1	"	3.5	3.5	
4	9:28	1	"	2	2	
5	9:30	2	"	1	0.5	
6	9:31	0	"	0	0	New record sheet
						Temp. changed, 9:31
7	9:32	1	25.5	3.5	3.5	
8	9:34	2	"	3	1.5	
9	9:35	1	"	6	6	
10	9:36	1	"	5.5	5.5	
11	9:37	1	"	6	6	
12	9:38	1	"	8	8	
13	9:39	1	"	5	5	
14	9:40	1	"	6	6	Interruption
						Temp. falling
15	9:44	0	24	0	0	New record sheet
16	9:45	1	"	8	8	
17	9:46	1	"	7.5	7.5	
						Temp. changed, 9:46:30
18	9:47	1	Variable	5	5	
19	9:48	1	10.5	2	2	
20	9:49	1	"	2	2	
21	9:52	3	"	3	1	
22	9:55	0	"	0	0	Interruption to 9:59
						New record sheet
23	9:59	0	"	0	0	
24	10:08	9	"	11	1.2	
25	10:16	8	"	6	0.8	
26	10:23	7	"	8	1.1	
27	10:24	1	"	2	2	
						Temp. changed, 10:25
28	10:26	2	Variable	4	2	
29	10:27	1	24.5	3	3	
30	10:28	1	"	3	3	
31	10:29	1	"	3.5	3.5	
32	10:30	1	"	3	3	
33	10:31	1	"	4	4	
34	10:32	1	"	6	6	
35	10:33	1	"	4	4	
36	10:34	1	"	4	4	
37	10:36	2	"	4	2	

No. of Observation	Time	Time Interval Min.	Temperature Degrees C	Total Distance Mm.	Rate Mm. per Min.	Remarks
38	10:37	1	24.5	3	3	
39	10:38	1	"	3.5	3.5	
						Temp. changed, 10:40
40	10:41	0	14.5	0	0	New record sheet
41	10:44	3	"	1.5	0.5	
42	10:47	3	"	3.5	1.2	


X

PERFORMANCE RECORD
of
INDIVIDUAL X

No. of Observation	Time	Time Interval Min.	Temperature Degrees C	Total Distance Mm.	Rate Mm. per Min.	Remarks
1	10:32	0	19.5	0	0	
2	10:33	1	"	7	7	
3	10:34	1	"	3	3	
4	10:35	1	"	7	7	
5	10:36	1	"	4	4	
6	10:37	1	"	5	5	
7	10:38	1	"	6	6	
8	10:39	1	"	8	8	
9	10:40	0	"	-	-	Temp. changed, 10:40:3
10	10:41	8	10.5	6	0.75	New record sheet
11	10:45		"			
12	10:49		"			
13	10:53	0	"	0	0	No observation
14	10:54	1	"	3.5	3.5	
15	10:55	1	10	4	4	Temp. changed, 10:54:30
16	10:56	1	"	3	3	
17	10:57	1	"	2	2	
18	10:58	1	"	3.5	3.5	
19	10:59	1	"	3	3	
21	11:00	0	"	0	0	New record sheet
22	11:01	1	Variable	4.5	4.5	Temp. changed, 11:01:30
23	11:02	1	23.5	5	5	
24	11:03	1	"	9	9	
25	11:04	1	"	9	9	
26	11:05	1	"	8	8	
27	11:06:15	1.25	Variable	2	1.6	Temp. changed, 11:06:30
28	11:09	2.75	11.5	3.5	1.3	
29	11:12	3	"	2	0.66	
30	11:17	0	"	0	0	Rest; began to move, 11:17
31	11:20	3	"	9	3	
32	11:22	2	Variable	3	1.5	Temp. changed, 11:22
33	11:23	1	24	6	6	
34	11:24	1	"	9	9	
35	11:25	1	"	10	10	
36	11:26	1	"	9	9	Temp. changed, 11:26:3

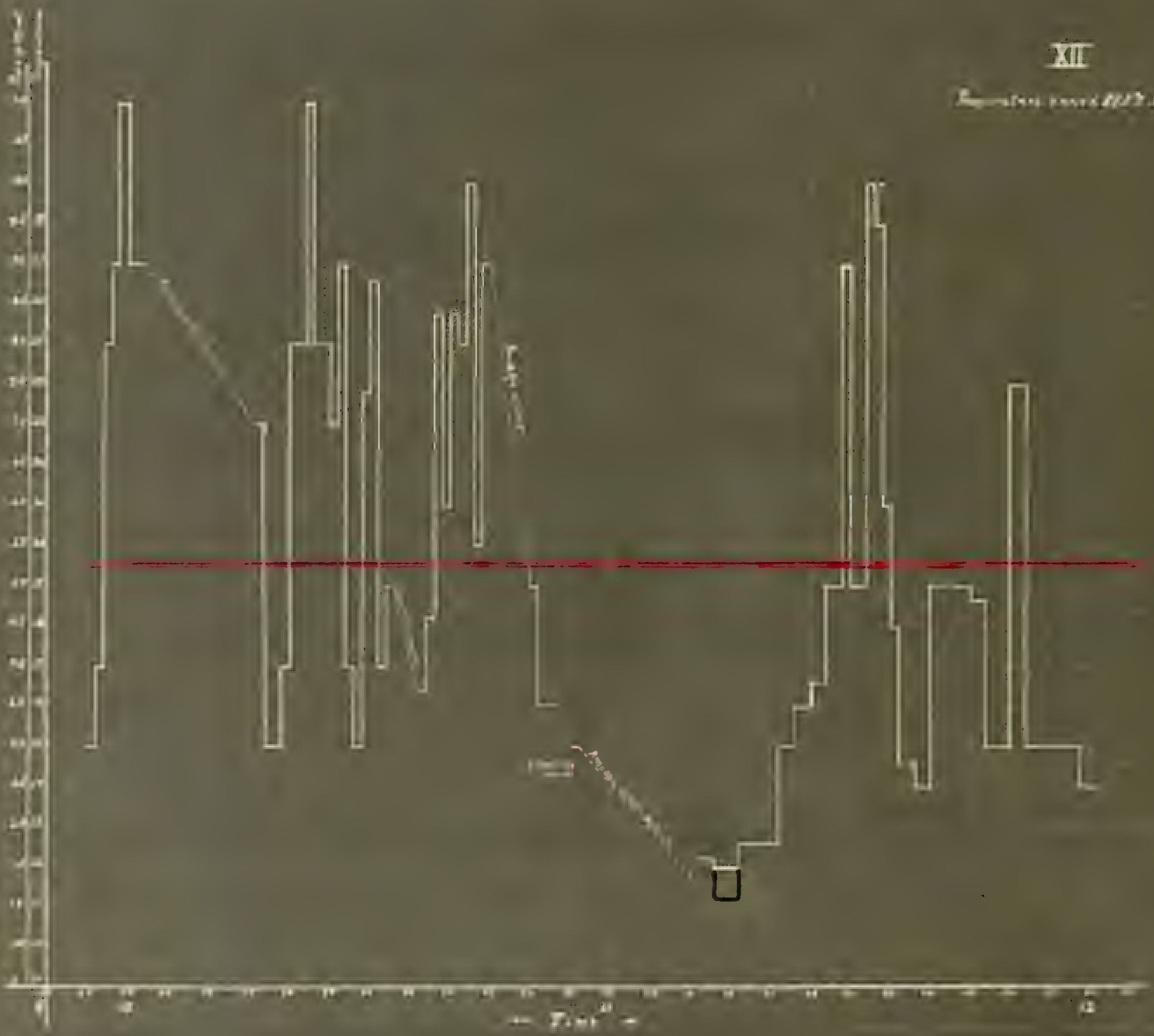
No. of Observation	Time	Time Interval Min.	Temperature Degrees C	Total Distance Mm.	Rate Mm. per Min.	Remarks
37	11:27	0	15	0	0	
38	11:28	1	"	2.5	2.5	
39	11:30	2	"	3.5	1.8	
40	11:31	1	"	2.5	2.5	
41	11:32	1	"	3	3	
42	11:33	1	"	3	3	
44	11:35	2	"	1.5	0.75	
45	11:38	3	"	2	0.66	
46	11:41	3	"	2.5	0.83	
47	11:42	1	"	4	4	
48	11:43	1	"	2	2	
49	11:45	2	"	2.5	1.25	
50	11:46	2	"	3	1.5	


XI

PERFORMANCE RECORD
of
INDIVIDUAL XI

No. of Observation	Time	Time Interval Min.	Temperature Degrees C	Total Distance Mm.	Rate Mm. per Min.	Remarks
1	11:47	0	15.5	0	0	
2	11:48	1	"	9	9	
3	11:49	1	"	7.5	7.5	
4	11:50	1	"	8	8	
5	11:51	1	"	9	9	
6	11:52	0	"	0	0	New record sheet
7	11:53	1	"	5	5	
8	11:54	1	"	10	10	Temp. changed, 11:54:15
9	11:55	1	11	3	3	
10	11:56	1	"	2	2	
11	11:57	1	"	4	4	
12	11:58	1	"	4	4	
13	12:00	2	"	3	1.5	
14	12:01	1	"	5	5	
15	12:02	0	"	0	0	New record sheet
16	12:03	1	"	6	6	
17	12:04	1	"	6	6	
18	12:05	1	"	3	3	
19	12:06	1	Variable	6	6	Temp. changed, 12:05:30
20	12:08	2	"	13	6.5	
21	12:09	1	23	13	13	Temp. fairly steady
22	12:10	0	"	0	0	New record sheet
23	12:11	1	"	10	10	
24	12:12	1	"	9.5	9.5	
25	12:13	1	"	9	9	
26	12:14	1	"	8	8	
27	12:16	2	"	14	7	
28	12:17	1	"	11	11	
29	12:18	1	"	12	12	
30	12:19	1	"	7	7	
31	12:20	1	"	6	6	
						Temp. changed, 12:20:30
32	12:21	1	10	9	9	
33	12:22	1	"	2	2	
34	12:23	1	"	2	2	
35	12:25	2	"	3.5	1.75	
36	12:27	2	"	7	3.5	
37	12:28	1	"	3.5	3.5	
38	12:30	2	"	3.5	1.75	
39	12:31	1	"	6	6	
40	12:32	1	"	7.5	7.5	
41	12:33	1	"	4	4	

No. of Observation	Time	Time Interval Min.	Temperature Degrees C	Total Distance Mm.	Rate Mm. per Min.	Remarks
42	12:35	2	10	10	5	
43	12:36	1	"	7.5	7.5	
44	12:37	1	"	8	8	
45	12:38	0	"	0	0	New record sheet
46	12:39	1	"	8	8	
47	12:40	1	"	3	3	
48	12:44	4	8 + 1	3	0.75	Temp. changed, 12:43
49	12:48	4	"	4	1	
50	12:50	2	"	2	1	
51	12:53	0	"	0	0	Interruption
52	12:55	2	"	6	3	
53	12:57	2	"	4	2	
54	1:03	6	"	13	2.1	
55	1:04	0	"	0	0	New record sheet
56	1:05	1	Variable	6	6	Temp. changed, 1:05
57	1:06	1	23	7	7	
58	1:07	1	"	8	8	
59	1:08	1	"	11	11	
60	1:09	1	"	8	8	
61	1:10	0	"	0	0	New record sheet
62	1:12	2	"	8	4	
63	1:13	1	"	5	5	
64	1:14	1	"	6	6	Temp. unsteady
65	1:15	1	"	11	11	


XII

PERFORMANCE RECORD
of
INDIVIDUAL XII

No. of Observation	Time	Time Interval Min.	Temperature Degrees C	Total Distance Mm.	Rate Mm. per Min.	Remarks
1	9:55	0	19.5	0	0	
2	9:56	1	"	3	3	
3	9:57	1	"	4	4	
4	9:58	1	"	8	8	
5	9:59	1	"	9	9	
6	10:00	1	"	11	11	
7	10:01	1	"	9	9	
8	10:02	1	"	9	9	Animal under debris
9	10:16	0	"	0	0	New record sheet
10	10:17	1	"	7	7	
11	10:18	1	"	3	3	
12	10:19	1	"	3	3	
13	10:20	1	"	4	4	
14	10:21	1	"	8	8	
15	10:22	1	"	8	8	
16	10:23	1	"	11	11	
17	10:24	0	"	0	0	New record sheet
18	10:25	1	"	8	8	
19	10:26	1	"	7	7	
20	10:27	1	"	9	9	
21	10:28	1	"	4	4	
22	10:29	1	"	3	3	
23	10:30:05	1.08	"	8	7.4	
24	10:31	0.9	"	8	8.8	
25	10:32	1	"	4	4	
26	10:33	1	"	5	5	
27	10:36	0	"	0	0	Interruption New record sheet
28	10:37:05	1.08	"	4	3.7	
29	10:38:10	1.08	"	5	4.6	
30	10:39	0.83	"	7	8.4	
31	10:40:10	1.16	"	7	6	
32	10:41	0.83	"	7	8.4	
33	10:42	1	"	8	8	
34	10:43	1	"	10	10	
35	10:44	1	"	5.5	5.5	
36	10:45	1	"	9	9	Rest; began to move, 10:50
38	10:50	0	"	0	0	New record sheet
39	10:51	1	"	5	5	Animal dragging debri
40	10:52	1	"	3.5	3.5	" " "
41	10:53	1	"	3.5	3.5	" " "
42	10:55	0	"	0	0	No observation made
43	10:56	1	"	3	3	Animal dragging debri
44	11:07	0	"	0	0	Animal under debris until 11:07
45	11:11	4	"	6.5	1.6	
46	11:13		"			
47	11:16	5	"	7.5	1.5	Change of direction
48	11:21	5	"	9	1.8	

No. of Observation	Time	Time Interval Min.	Temperature Degrees C	Total Distance Mm.	Rate Mm. per Min.	Remarks
49	11:23	2	19.5	6	3	
50	11:25	2	"	7	3.5	
51	11:27	2	"	7.5	3.8	
52	11:29	2	"	10	5	
53	11:30	1	"	9	9	
54	11:31	1	"	5	5	
55	11:32	1	"	5	5	
56	11:32:30	0	"	0	0	New record sheet
57	11:33	0.5	"	5	10	
58	11:34	1	"	9.5	9.5	
59	11:35	1	"	6	6	
60	11:36	1	"	4.5	4.5	
61	11:38	2	"	5.5	2.8	
62	11:40	2	"	5	2.5	
63	11:42	2	"	10	5	
64	11:43	0	"	0	0	New record sheet
65	11:45	2	"	10	5	
66	11:47	2	"	9.5	4.8	
67	11:50	3	"	9	3	
68	11:52	2	"	15	7.5	
69	11:53	1	"	3	3	
70	11:55	2	"	6	3	
71	11:57	2	"	6	3	
72	11:59	2	"	6	3	
73	12:01	2	"	5	2.5	

PERFORMANCE RECORD

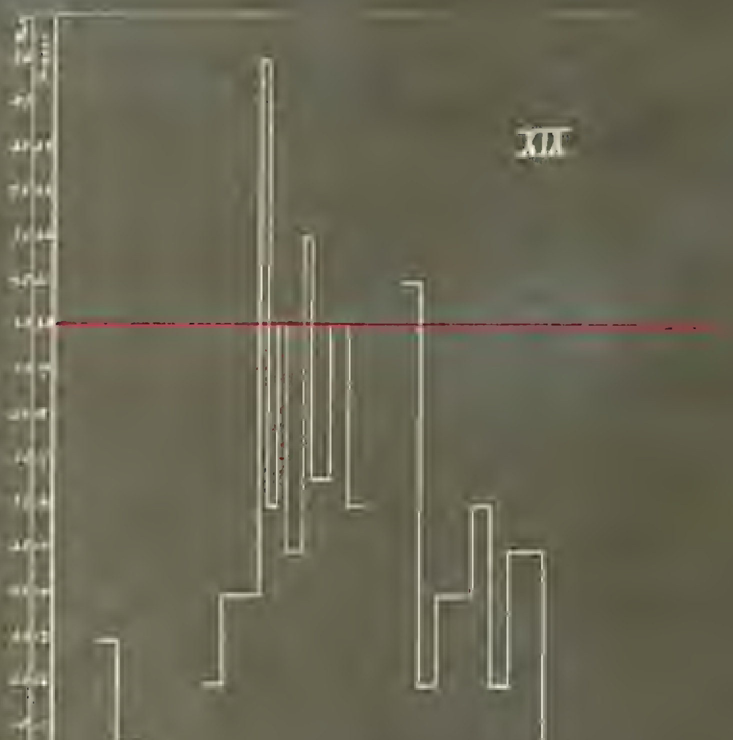
of

INDIVIDUAL XIII

No. of Observation	Time	Time Interval Min.	Temperature Degrees C	Total Distance Mm.	Rate Mm. per Min.	Remarks
1	2:12	0	20	0	0	
2	2:13	1	"	3.5	3.5	
3	2:14	1	"	3	3	
4	2:15	1	"	4.5	4.5	
5	2:16	1	"	2	2	
6	2:18	2	"	4	2	
7	2:20	2	"	11	5.5	
8	2:25	5	"	12	2.4	
9	2:27	2	"	7	3.5	
10	2:29	2	"	6	3	
11	2:31	2	"	9	4.5	
12	2:33	2	"	6	3	
13	2:35	2	"	13	6.5	
14	2:36:15	0	"	0	0	New record sheet
15	2:38	1.75	"	7	4	
16	2:41	3	"	4	1.3	
17	2:43	2	"	4	2	
18	2:48	5	"	4	0.8	
19	2:50	2	"	10	5	
20	2:52	2	"	2	1	
21	2:58	6	"	12	2	
22	3:00	2	"	2	1	
23	3:06	6	"	4.5	0.7	
24	3:12	6	"	9	1.5	
25	3:15	0	"	0	0	New record sheet Temp. changed, 3:14:30
26	3:16	1	26	3	3	
27	3:18	2	"	3	1.5	
28	3:20	2	"	6	3	
29	3:23	3	"	13	4.3	
30	3:25	2	"	4	2	
31	3:30	5	"	3.5	0.7	
32	3:35	5	"	2	0.4	No locomotion for almost one hour, 3:35 - 4:33
33	3:46	0	"	-	-	
34	4:00	0	"	-	-	
35	4:10	0	"	-	-	
36	4:13	0	"	-	-	Temp. changed, 4:13
37	4:16	0	Variable	-	-	
38	4:21	0	"	-	-	
39	4:29	0	15	-	-	
40	4:33	0	"	0	0	New record sheet
41	4:36	3	"	6	2	

XIII - (2)

No. of Observation	Time	Time Interval Min.	Temperature Degrees C	Total Distance Mm.	Rate Mm. per Min.	Remarks
42	4:39	3	16	6	2	Variations in temp., 4:36 - 4:52, as indicated
43	4:41	2	14	5	2.5	
44	4:43	2	"	4	2	
45	4:46	0	"	0	0	Brief rest
46	4:48	2	"	6	3	
46a	4:48:30	0	"	0	0	New record sheet
47	4:50	1.5	16	4.5	3	
48	4:52	2	15	5	2.5	
49	4:54	2	14	5	2.5	
50	4:56	2	15	4	2	
51	4:58	2	"	5	2.5	
52	5:00	2	"	6	3	
53	5:02	2	"	3	1.5	
54	5:04	2	"	6	3	
55	5:05	0	"	0	0	New record sheet
56	5:06	1	24	3	3	
57	5:07	1	"	6.5	6.5	
58	5:08	1	"	2.5	2.5	
59	5:10	2	"	3	1.5	



PERFORMANCE RECORD
of
INDIVIDUAL XIV

No. of Observation	Time	Time Interval Min.	Temperature Degrees C	Total Distance Mm.	Rate Mm. per Min.	Remarks
1	10:30	0	20	0	0	
2	10:32	2	"	4.5	2.25	
3	10:34	2	"	3.5	1.75	
4	10:36	2	"	2	1	
5	10:38	2	"	4.5	2.25	
6	10:40	2	"	2.5	1.25	
7	10:42	2	"	3.5	1.75	
8	10:45	3	"	5	1.7	
9	10:46	0	"	0	0	New record sheet
10	10:48	2	"	1.5	0.75	
11	10:50	2	"	4.5	2.25	
12	10:53	3	"	1.5	0.5	
13	10:55	2	"	1	0.5	
14	11:00	5	"	2.5	0.5	Temp. changed, 11:00
15	11:03	0	10	0	0	New record sheet
16	11:10	7	"	3	0.4	
17	11:15	5	13	4.5	0.9	Temp. changed, 11:15
18	11:26	0	10	0	0	No movement Temp. changed, 11:29:3
19	11:30	4	19.5	3	0.7	
20	11:32	2	"	2	1	
21	11:34	2	"	4	2	

FOLD OUT

PERFORMANCE RECORD

of

INDIVIDUAL XV

No. of Observation	Time	Time Interval Min.	Temperature Degrees C	Total Distance Mm.	Rate Mm. per Min.	Remarks
1	1:57	0	18	0	0	
2	1:59	2	"	5	2.5	
3	2:01	2	"	6.5	3.25	Temp. changed, 2:02:30
4	2:03	2	18.5	6.5	3.25	
5	2:05	2	"	4	2	
6	2:06	0	"	0	0	New record sheet
7	2:08	2	"	2	1	
8	2:10	2	"	4	2	
9	2:12	2	"	6	3	
10	2:14	2	"	6.5	3.25	
11	2:16	2	"	2	1	
12	2:18	2	"	3.5	1.75	
13	2:20	2	"	10	5	
14	2:21	0	"	0	0	New record sheet
15	2:23	2	"	7.5	3.75	
16	2:26	3	"	14	4.66	
17	2:30	4	"	22.5	5.62	
18	2:32	2	"	7.5	3.75	
19	2:33	0	"	0	0	Interruption
20	2:35	2	10.5	3	1.5	Temp. changed, 2:34:30
21	2:37	0	"	0	0	New record sheet
22	2:39	2	"	4	2	
23	2:41	2	"	6.5	3.25	
24	2:44	3	"	8.5	2.83	
25	2:46	2	"	8	4	
26	2:48	2	"	8	4	
27	2:50	2	"	4	2	
28	2:53	3	"	9	3	
29	2:56	3	"	9.5	3.17	
30	2:58	2	"	5	2.5	
31	3:01:30	3.5	"	16.5	4.71	
32	3:04	2.5	"	8.5	3.4	
33	3:06	0	"	0	0	New record sheet
34	3:08	2	"	7	3.5	
35	3:11	3	11	10	3.3	Temp. changed, 3:10:30
36	3:13	2	"	9	4.5	
37	3:15	2	"	7	3.5	
38	3:17	2	"	7	3.5	
39	3:19	2	"	7	3.5	
40	3:21	2	"	8.5	4.25	
						Interruption
42	3:23	2	"	9	4.5	
43	3:24	0	"	0	0	New record sheet

XV - (2)

No. of Observation	Time	Time Interval Min.	Temperature Degrees C	Total Distance Mm.	Rate Mm. per Min.	Remarks
44	3:27	3	11.	3.5	1.2	
45	3:30	3	"	10	3.3	
46	3:33	3	"	18	6	
47	3:35	0	"	0	0	New record sheet
48	3:38	3	"	5	1.7	
49	3:40	2	"	13	6.5	
50	3:43	3	"	11.5	3.8	
51	3:45	2	"	5.5	2.75	
52	3:48	3	"	10.5	3.5	
53	3:50	2	"	3	1.5	
54	3:53	3	"	6	2	
55	3:55	2	"	6	3	
56	3:56	0	"	0	0	New record sheet Temp. changed, 3:56
57	3:59		10			
58	4:02	9	"	8	0.9	
59	4:05		"			
60	4:11	6	"	5	0.8	
61	4:14	3	"	5	1.7	
62	4:18	4	"	5.5	1.4	Temp. changed, 4:17:30
63	4:22	4	10.5	7	1.8	
64	4:25	3	"	4	1.3	
65	4:30	5	10	2	0.4	Temp. changed, 4:29:30
66	4:34	4	"	4.5	1.1	
67	4:39	5	"	6	1.2	
68	4:43	4	"	3	0.75	
69	4:48	5	"	4	0.8	
70	4:53	5	"	4.5	0.9	
71	4:57	4	"	4	1	
72	5:02	5	"	4.5	0.9	
73	5:05	3	"	1	0.3	Temp. changed, 5:07:30
74	5:08	3	26	3	1	
75	5:08:30		"			
75b	5:12:30	9.5	"	4.5	0.5	
75c	5:15		"			
76	5:18					

FOLD OUT

PERFORMANCE RECORD

of

INDIVIDUAL XVI

No. of Observation	Time	Time Interval Min.	Temperature Degrees C	Total Distance Mm.	Rate Mm. per Min.	Remarks
1	11:26:30	0	20	0	0	
2	11:27:30	1	"	2	2	
3	11:28:30	1	"	3	3	
4	11:29:30	1	"	11	11	
5	11:30:30	1	"	14	14	
6	11:31:30	1	"	7	7	
7	11:35	3.5	"	17	5	
8	11:37	2	"	5.5	2.75	
9	11:38	1	"	4	4	
10	11:40	0	"	0	0	New record sheet
11	11:41	1	"	4.5	4.5	
12	11:42	1	"	2.5	2.5	
13	11:44	2	"	2.5	1.25	
14	11:47	3	"	1.5	0.5	
15	11:51	4	"	2	0.5	
16	11:56	5	"	3	0.6	
17	11:58	2	"	2	1	
18	12:00	2	"	3	1.5	
19	12:03	3	"	3	1	
20	12:04	0	"	0	0	New record sheet
21	12:05	3	"	4	1.33	
22	12:07		"			
23	12:09	2	"	4	2	
24	12:11	2	"	3	1.5	
25	12:14:30	0.	"	0	0	New record sheet
26	12:15:30	1	"	2	2	Rest; began to move, 12:16:30
						Temp. changed, 12:17
27	12:17:30	1	26	4.5	4.5	
28	12:18:30	1	"	6	6	
29	12:19:30	1	"	6	6	
30	12:20:30	1	"	4	4	
31	12:21:30	1	"	4	4	
32	12:22:30	1	"	2.5	2.5	
33	12:24:30	2	"	4	2	
34	12:25:30	1	"	4	4	
35	12:26:30	1	"	6	6	
36	12:27:30	1	27	6	6	Temp. changed, 12:27
37	12:28:30	1	"	5.5	5.5	
38	12:29:30	1	"	6	6	
39	12:30:30	1	26	6	6	Temp. changed, 12:30
40	12:31:30	1	"	9	9	
41	12:32	0.	"	0	0	New record sheet
42	12:35	3	24	17	5.7	Temp. changed, 12:34:30

No. of Observation	Time	Time Interval Min.	Temperature Degrees C	Total Distance Mm.	Rate Mm. per Min.	Remarks
43	12:36	1	24	7	7	
44	12:37	1	"	8.5	8.5	
45	12:38	1	"	5.5	5.5	
46	12:39	1	"	4	4	
47	12:40	0	26	0	0	Change of direction
48	12:41	1	"	4.5	4.5	
49	12:42	1	"	4.5	4.5	
50	12:42:30	0.	28	0	0	New record sheet
51	12:43:30	1	"	5	5	
52	12:44:30	1	"	7	7	
53	12:45:30	1	26	12	12	Temp. changed, 12:45
54	12:46:30	1	"	12	12	
55	12:47:30	1	"	3	3	
56	12:48:30	1	"	9	9	
57	12:49:30	1	"	8	8	
58	12:51	1.5	30	8	5.3	
59	12:52	1	"	8	8	
60	12:53	1	"	8	8	
61	12:54	1	"	5	5	
62	12:55	0	"	0	0	New record sheet
63	12:56:10	1.16	"	9	7.7	
64	12:57	.8	"	6.5	7.8	
65	12:58	1	"	3.5	3.5	
66	12:59	1	"	16	16	
67	1:00:05	1.08	"	13	12	
68	1:01	.92	"	6	6.6	
69	1:02:20	0	"	0	0	New record sheet
70	1:03:20	1	"	4	4	
71	1:04:20	1	"	4	4	
72	1:06:20	2	"	4	2	
73	1:07	0	28	0	0	New record sheet
74	1:08	1	"	6.5	6.5	
75	1:09	1	"	4	4	
76	1:10	1	"	4.5	4.5	
77	1:12	2	"	10	5	
78	1:13	1	"	8.5	8.5	
79	1:15	2	"	19	9.5	
80	1:16:10	1.16	"	11	9.5	
81	1:20:30	0	"	0	0	New record sheet
82	1:21	.5	"	3.5	7	
83	1:22	1	"	2	2	
84	1:23	1	"	3	3	

XVI - (3)

No. of Observation	Time	Time Interval Min.	Temperature Degrees C	Total Distance Mm.	Rate Mm. per Min.	Remarks
85	1:24	1	28	3.5	3.5	
86	1:26	2	"	6	3	
87	1:29	3	"	7	2.3	
88	1:32	0	11 ± 1	0	0	New record sheet Temp. changed, 11:31:30
89	1:37	5	"	10	2	
90	1:45		"			
90a	1:46		"			
91	2:02:30		"			
91a	2:18		"			
92	2:20	52.5	"	6	0	
93	2:22		"			
94	2:26		"			
95	2:28		"			
96	2:30		"	0	0	New record sheet
97	2:32	2	8	6	3	
98	2:34	2	"	5	2.5	
99	2:37	3	"	6	2	
100	2:39	2	"	7.5	3.75	
101	2:41	2	"	3	1.5	
102	2:42	0	"	0	0	New record sheet
103	2:45	3	"	3.5	1.2	
104	2:48	3	"	3.5	1.2	
105	2:51	3	"	3	1	
106	2:57	6	"	9	1.5	
107	3:00	3	"	5	1.6	
108	3:03	3	"	4	1.3	
109	3:06	3	"	3	1	
110	3:10	9	"	11	1.2	
111	3:15		"			
113	3:20	5	"	4	0.8	
114	3:25	0	"	0	0	New record sheet
115	3:30	5	16	8.5	1.7	Temp. changed, 3:29:30
116	3:35	5	"	25	5	
116a	3:35:30	0	"	0	0	New record sheet
117	3:36	0.5	17	2.5	5	Temp. rising slowly
118	3:38	2	18	6	3	

XVI - (4)

No. of Observation	Time	Time Interval Min.	Temperature Degrees C	Total Distance Mm.	Rate Mm. per Min.	Remarks
119	3:40	2	19	8	4	
120	3:42	2	20	5	2.5	
121	3:43	1	"	6.5	6.5	
123	3:44	1	"	7	7	
124	3:45	0	"	0	0	New record sheet
125	3:46	1	"	8	8	
126	3:47	1	"	6	6	
127	3:48	1	"	7	7	
128	3:49	1	"	5	5	
129	3:49:45	0	"	0	0	New record sheet
130	3:51	1.25	"	4	3.2	
131	3:52	1	"	4	4	
132	3:54	2	"	5	2.5	
133	3:56	2	"	10	5	
134	3:58	2	"	6	3	
135	4:00	2	"	6	3	

FOLD OUT

PERFORMANCE RECORD

of

INDIVIDUAL XVII

No. of Observation	Time	Time Interval Min.	Temperature Degrees C	Total Distance Mm.	Rate Mm. per Min.	Remarks
1	12:16	0	23	0	0	
2	12:17	1	"	6	6	Temp. changed, 12:17:30
3	12:18	1	20	11	11	
4	12:19	1	"	6	6	
5	12:20	1	"	7	7	
6	12:21	1	"	6	6	
7	12:22	1	"	3	3	
8	12:23	1	"	6	6	
9	12:24	0	"	0	0	New record sheet
10	12:25	1	"	2	2	
12	12:26	1	"	5	5	
13	12:27	1	"	8	8	
14	12:28	1	"	7	7	
15	12:29	1	"	7	7	
16	12:30:30	1.5	"	12	8	
17	12:31	.5	"	3	6	
18	12:32	1	"	3.5	3.5	
19	12:33	1	"	10	10	
20	12:34	1	"	9	9	
21	12:35	1	"	8	8	
22	12:36	1	"	6	6	
23	12:37	1	"	10	10	
24	12:38:05	1.08	"	9	8.3	
25	12:39:05	1	"	7	7	
26	12:40:15	1.16	"	8	7	
27	12:41:15	1	"	2.5	2.5	
28	12:43	0	"	0	0	Rest; began to move, 12:44
29	12:45	2	"	3	1.5	
30	12:47	2	"	12	6	
31	12:48	1	"	8	8	
32	12:49	1	"	4	4	
33	12:50	1	"	7	7	
34	12:51	1	"	7	7	
35	12:52	1	"	10	10	
36	12:53	1	"	8	8	
37	12:54	1	"	8	8	
38	12:55	0	"	0	0	New record sheet
39	12:56	1	"	7.5	7.5	
40	12:58	0	15	0	0	New starting point
41	12:59	1	"	2.5	2.5	
42	1:00	1	"	4	4	
43	1:02	0	"	0	0	New record sheet
44	1:03:15	2	"	7	3.5	
45	1:04		"			
46	1:05	0	"	0	0	New record sheet

XVII - (2)

No. of Observation	Time	Time Interval Min.	Temperature Degrees C	Total Distance Mm.	Rate Mm. per Min.	Remarks
47	1:07	2	15	9	4.5	
48	1:09	2	"	3	1.5	
49	1:11	2	"	4	2	
50	1:13:30	0	"	0	0	New record sheet
51	1:15	1.5	"	5.5	3.66	
52	1:17	2	"	7.5	3.75	
53	1:19	2	"	2.5	1.25	
54	1:21	2	"	5.5	2.75	
55	1:23	2	"	3.5	1.75	
56	1:25	2	"	2	1	Animal divided, 1:26 Rest; began to move, 1:28
57	1:29	1	"	4	4	Rest; began to move, 1:46
58	1:46	0	"	0	0	
59	1:48	2	"	3.5	1.75	
60	1:50	2	"	2	1	
61	1:52	0	"	0	0	Rest; began to move very slowly, 1:52
62	1:54		"			
63	1:56		"			
64	1:58	8	"	12	1.5	
65	2:00		"			
						Rest; began to move, 2:05
66	2:05	8	"	4.5	0.56	
67	2:08		"			
68	2:10		"			
69	2:12	7	"	7	1	
70	2:15		"			
71	2:17	5	"	6	1.2	
72	2:20		"			
73	2:22	6	"	8	1.3	
74	2:26		"			
75	2:27	0	"	0	0	New record sheet
76	2:30	3	"	2	0.7	
77	2:34	4	"	2	0.5	
78	2:37	3	"	3	1	
79	2:40		"			
80	2:41	5	"	8.5	1.7	
81	2:42		"			
82	2:43	0	"	0	0	No observation made
83	2:45	2	"	3.5	1.7	
84	2:47		"			
85	2:50	5	"	12	2.4	
86	2:51	0	"	0	0	New record sheet Rest; began to move, 3:04
87	3:04	0	15.5	0	0	Temp. changed, 3:04

XVII • (3)

No. of Observation	Time	Time Interval Min.	Temperature Degrees C	Total Distance Mm.	Rate Mm. per Min.	Remarks
88	3:07	3	15.5	5.5	1.8	
89	3:10	3	"	3	1	
90	3:16	0	"	0	0	New starting point
91	3:18	2	"	2	1	
92	3:20	2	"	2	1	
93	3:21	1	"	2.5	2.5	
94	3:23	4	"	5	1.2	
95	3:25		"			
96	3:27		20.5			Temp. changed, 3:27
97	3:29		"			
98	3:31	8	"	12	1.5	
99	3:33		"			
100	3:35		"			
101	3:38	9	"	5	0.45	
102	3:42		"			
103	3:44:30	0	"	0	0	New record sheet
104	3:46		"			
105	3:48	7.5	"	10	1.3	
106	3:50		"			
107	3:52		"			
108	3:55	0	"	0	0	New record sheet
109	3:57	2	"	3.5	1.7	
110	3:59	2	"	3	1.5	
111	4:01	2	"	4	2	
112	4:03	0	"	0	0	New record sheet
113	4:05	2	"	2	1	
114	4:07	2	"	2	1	

<u>Individual XVII a</u>

65	2:00	0	15	0	0
66	2:05	5	"	3.5	0.7
67	2:08	3	"	4	1.3
68	2:10	2	"	2	1
69	2:12:15	2.25	"	7	3
70	2:15	2.75	"	3	1
71	2:17	2	"	9	4.5
72	2:20	3	"	8	2.6

FOLD OUT

PERFORMANCE RECORD

of

INDIVIDUAL XVIII

No. of Observation	Time	Time Interval Min.	Temperature Degrees C	Total Distance Mm.	Rate Mm. per Min.	Remarks
1	10:34		20			
2	10:35		"			Very slow movement
3	10:36		"			
4	10:38		"			
5	10:39	13	"	12	1	
6	10:40		"			
7	10:42		"			
8	10:44		"			
9	10:47		"			
10	10:48	0	"	0	0	New record sheet
11	10:50	2	"	3	1.5	
12	10:53	3	"	6	2	
13	10:55	2	"	8	4	
14	10:58	3	"	17	5.7	
15	11:00	2	"	7	3.5	
16	11:02	2	"	4	2	
17	11:05	3	"	7	2.3	
18	11:07:30	0	"	0	0	New record sheet
19	11:11	3.5	"	9	2.6	
20	11:12	1	"	5	5	
21	11:15	0	"	0	0	New record sheet
22	11:18	3	"	3	1	
23	11:23	5	"	18	3.6	
24	11:25	2	"	4	2	
25	11:28	3	"	4.5	1.5	
26	11:30	2	"	9	4.5	
27	11:32	0	"	0	0	New record sheet
28	11:34	2	"	4.5	2.25	
29	11:38	4	"	20	5	
30	11:40	2	"	7	3.5	
31	11:42	2	"	9.5	4.7	
32	11:55	0	"	0	0	Observations interrupt
33	11:57	2	"	4	2	
34	12:00	3	"	2	0.7	
35	12:02	2	"	10	5	
36	12:03	1	"	6	6	Temp. changed, 12:04
37	12:05	2	16	14	7	
38	12:08	3	"	13	4.3	
39	12:09	1	"	6	6	
40	12:11	0	"	0	0	New record sheet
41	12:13	2	"	5	2.5	
42	12:15	2	"	5	2.5	
43	12:17	2	"	13	6.5	
44	12:19	2	"	4.5	2.25	
45	12:21	2	"	9	4.5	
46	12:24	3	"	11.5	3.8	
47	12:26:15	2.25	"	5	2.2	

XVIII - (2)

No. of Observation	Time	Time Interval Min.	Temperature Degrees C	Total Distance Mm.	Rate Mm. per Min.	Remarks
48	12:28	1.75	16	9	5.1	
49	12:29	0	"	0	0	New record sheet
50	12:30	0	"	-	-	
51	12:32	2	"	6	3	
52	12:34	2	"	4	2	
53	12:36	2	"	10	5	
54	12:38	2	"	5	2.5	
55	12:40	2	"	5	2.5	
56	12:42	2	"	4	2	
57	12:44	2	"	5	2.5	
58	12:45	0	"	0	0	New record sheet
59	12:47	2	"	8	4	
60	12:49	2	"	8	4	
61	12:51	2	"	5	2.5	
62	12:53	2	"	4	2	
63	12:55	2	"	6	3	
64	12:57	2	"	3	1.5	
65	1:02	0	"	0	0	New record sheet
66	1:05	3	"	3.5	1.1	
67	1:07	2	"	5.5	2.75	
68	1:10	3	"	7	2.3	
69	1:15	5	"	6	1.2	
70	1:17	2	"	10.5	5.2	
71	1:19	2	"	4	2	
72	1:21	2	"	5	2.5	
73	1:24	0	"	0	0	New record sheet
74	1:26	2	"	12	6	
75	1:28	2	"	7	3.5	
76	1:30	2	"	9.5	4.7	
77	1:32	2	"	7	3.5	
78	1:34	2	"	5	2.5	
79	1:36	2	"	4	2	Rest; began to move, 1:45
80	1:46	0	"	0	0	New record sheet
81	1:48	2	"	8	4	
82	1:50	2	"	6	3	
83	1:53	3	"	10	3.3	
84	1:56	3	"	9	3	
85	1:57	0	"	0	0	New record sheet
86	2:00	3	"	7	2.3	
87	2:02	2	"	8	4	
88	2:04	2	"	10	5	
89	2:06	2	"	12	6	
90	2:08	2	"	4	2	
91	2:10	2	"	4	2	
92	2:12	2	"	5	2.5	
93	2:14	2	"	6	3	
94	2:17	3	"	9	3	
95	2:22	5	"	18	3.6	Temp. changed, 2:23

XVIII - (3)

No. of Observation	Time	Time Interval Min.	Temperature Degrees C	Total Distance Mm.	Rate Mm. per Min.	Remarks
96	2:23:30	0	20	0	0	New record sheet
97	2:24:30	1	"	4	4	
98	2:26	1.5	"	7	4.7	
99	2:28	2	"	17	8.5	
100	2:30	2	"	13	6.5	
101	2:32	2	"	7	3.5	
102	2:34	2	"	8	4	
103	2:36	2	"	8	4	
104	2:38:30	2.5	"	4	1.6	
105	2:41	2.5	"	3	1.2	
106	2:43	2	"	7	3.5	
107	2:44	0	"	0	0	New record sheet
108	2:46	2	"	14	7	
109	2:53	7	"	8	1.1	

PERFORMANCE RECORD

of

INDIVIDUAL XIX *

No. of Observation	Time	Time Interval Min.	Temperature Degrees C	Total Distance Mm.	Rate Mm. per Min.	Remarks
1	9:05	0	20	0	0	
2	9:07	2	"	5	2.5	
3	9:10	3	"	4	1.3	
4	9:12	0	"	0	0	New starting point
5	9:14	2	"	2	1	
6	9:16	2	"	2	1	
7	9:17:30	0.	"	0	0	New record sheet
8	9:19	1.5	"	3	2	
9	9:21	2	"	6	3	
10	9:23	2	"	6	3	
11	9:24	1	"	9	9	
12	9:25	1	"	4	4	
13	9:26	1	"	6	6	
14	9:28	2	"	7	3.5	
15	9:29	1	"	7	7	
16	9:29:30	0	"	0	0	New record sheet
17	9:31	1.5	"	6.5	4.3	
18	9:33	2	"	12	6	
19	9:35	2	"	8	4	
20	9:37	0	"	0	0	New record sheet Rest; began to move, 9:39
21	9:41	2	"	13	6.5	
22	9:43	2	"	4	2	
23	9:45	2	"	6	3	
24	9:47	2	"	6	3	
25	9:49	2	"	8	4	
26	9:51	2	"	4	2	
27	9:53	2	"	7	3.5	
28	9:55	2	"	7	3.5	
29	9:57	2	"	2	1	

*Graph on same Plate with Individual XIV.

FOLD OUT

PERFORMANCE RECORD
of
INDIVIDUAL XX

No. of Observation	Time	Time Interval Min.	Temperature Degrees C	Total Distance Mm.	Rate Mm. per Min.	Remarks
1	11:04	0	20	0	0	
2	11:07	3	"	5	1.7	
3	11:09	2	"	3	1.5	Rest; began to move, 11:29
4	11:29	0	"	0	0	
7	11:35	6	"	6	1	Rest; began to move, 11:37
8	11:40	3	"	4	1.33	Rest; began to move, 11:44
10	11:47	3	"	3.5	1.2	
11	11:50	3	"	8	2.7	
12	11:52	2	"	13	6.5	
13	11:53	1	"	8.5	8.5	
14	11:54	1	"	3	3	
15	11:55	0	"	0	0	New record sheet
16	11:57	2	"	8	4	
17	11:59	2	"	8	4	
18	12:01	2	"	8	4	
19	12:03	0	"	0	0	New record sheet
20	12:05	2	"	10	5	
21	12:08	3	"	9	3	Rest; began to move, 12:10
22	12:15	5	"	4	0.8	New starting point
23	12:20	5	"	10	2	
24	12:22	2	"	10	5	
25	12:23:30	0	"	0	0	New record sheet
26	12:25	1.5	"	4	2.7	
27	12:28	3	"	4	1.3	
						Temp. changed, 12:31 Rest; began to move, 1:32
29	1:32	0	11	0	0	New starting point
30	1:38	6	"	6	1	
31	1:43	5	"	6	1.2	
32	1:46	3	"	6	2	
33	1:49:30	3.5	"	6	1.7	
34	1:53	3.5	"	7	2	
35	1:56	3	"	4	1.3	
36	2:01	5	"	4	0.8	
37	2:04	3	"	4	1.3	
39	2:08	0	"	0	0	New record sheet
40	2:12	3	"	2	0.66	Rest; began to move, 2:15
41	2:19	4	"	8	2	
42	2:22	3	"	6	2	
43	2:25	3	"	5	2	

FOLD OUT

PERFORMANCE RECORD

of

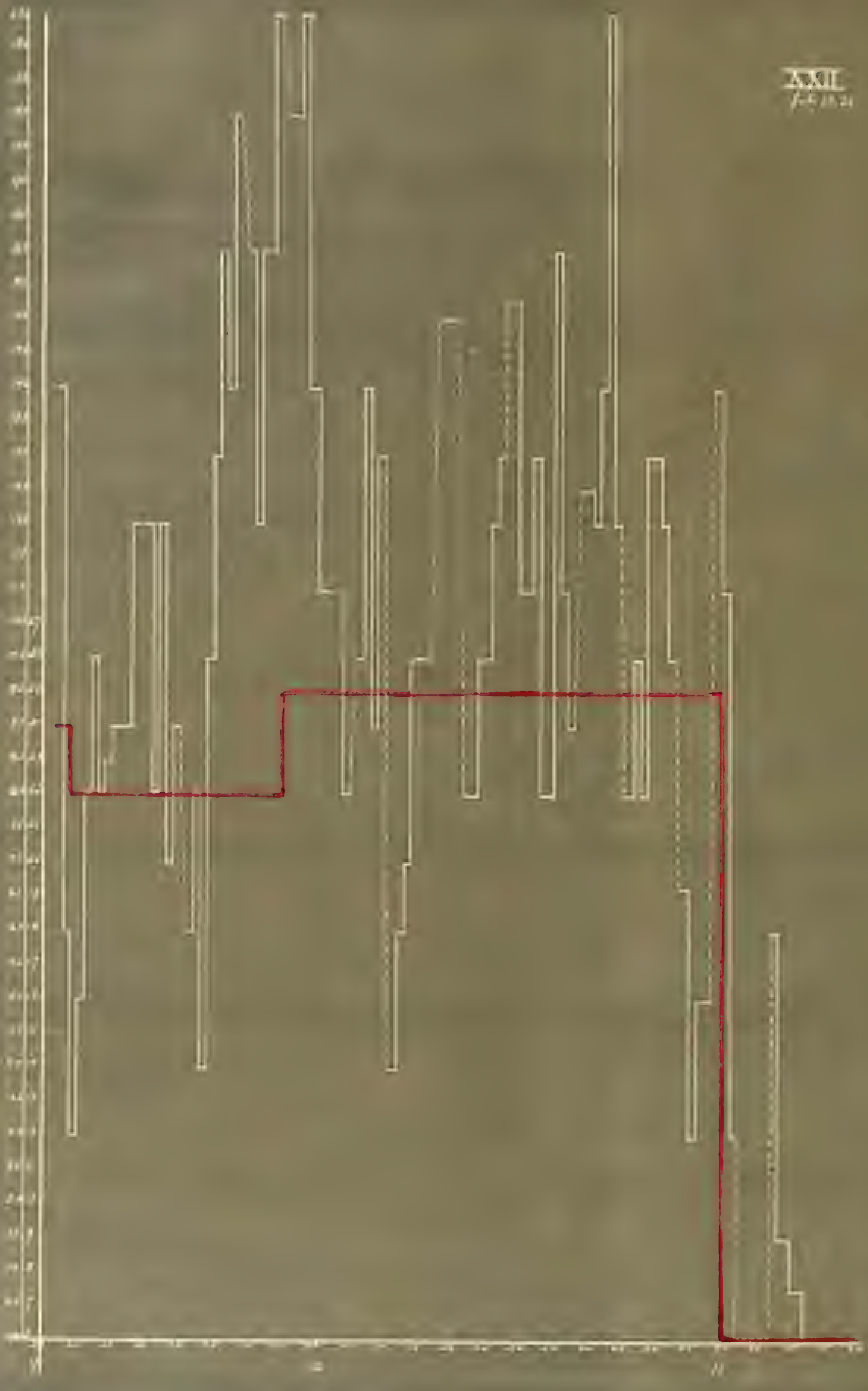
INDIVIDUAL XXI

No. of Observation	Time	Time Interval Min.	Temperature Degrees C	Total Distance Mm.	Rate Mm. per Min.	Remarks
1	10:42	0	22.5	0	0	
2	10:43	1	"	8	8	
3	10:44	1	"	8	8	
4	10:45	1	"	11	11	
5	10:46	1	"	9	9	
6	10:47	1	"	5	5	
7	10:48	1	"	4	4	
8	10:51	0	"	0	0	New record sheet
9	10:52	1	"	6.5	6.5	
10	10:53	1	"	9	9	
11	10:54	1	"	2.5	2.5	
12	10:55	1	"	2.5	2.5	
13	10:56	1	"	5	5	
14	10:57	1	"	5	5	
15	10:58	1	"	6	6	
16	10:59	1	"	3.5	3.5	
17	11:00	1	"	10	10	
18	11:01	1	"	5	5	
19	11:02	1	"	6	6	
20	11:03	1	"	6	6	
21	11:04	1	"	3	3	
22	11:05	1	"	3	3	Rest; began to move, 11:14
24	11:14	0	"	0	0	
25	11:15	1	"	2	2	
26	11:16	1	"	2	2	
27	11:18:30	0	"	0	0	New record sheet
28	11:20	1.5	"	10	6.6	
29	11:21	1	"	3.5	3.5	
30	11:22	1	"	3.5	3.5	
31	11:24	2	"	10	5	
32	11:25	1	"	8.5	8.5	
33	11:26	1	"	5	5	
34	11:27	1	"	5	5	
35	11:28	1	"	5.5	5.5	
36	11:29	1	"	7	7	
37	11:30	1	"	7	7	
38	11:31	0	"	0	0	New record sheet
39	11:32	1	"	8	8	
40	11:33	1	"	8	8	
41	11:34	1	"	7	7	
42	11:36	2	"	19	9.5	
43	11:37	1	"	9	9	
44	11:38	1	"	9	9	
45	11:39	1	"	6	6	Rest; began to move, 11:40
46	11:41	1	"	3	3	
47	11:42	1	"	3	3	
48	11:43	1	"	3	3	

No. of Observation	Time	Time Interval Min.	Temperature Degrees C	Total Distance Mm.	Rate Mm. per Min.	Remarks
49	11:44	1	22.5	4	4	
50	11:45	1	"	3	3	
51	11:47	2	"	2.5	1.25	Temp. changed, 11:47
52	11:51:30	0	26	0	0	New record sheet
53	11:53	1.5	"	10	6.66	
54	11:54	1	"	3	3	
55	11:55	1	"	8	8	
56	11:56	1	"	6	6	
57	11:57	1	"	7	7	
58	11:58	1	"	8	8	
59	12:00	2	"	9	4.5	
60	12:04	0	"	0	0	New record sheet
61	12:06	2	"	4	2	
62	12:08	2	"	6.5	3.25	
63	12:10	2	"	7	3.5	
64 65	12:11	1	"	9	9	
65	12:20	0	"	0	0	New record sheet
66	12:22	2	"	8	4	
67	12:24	2	"	4	2	Rest; began to move, 12:28
68	12:28	0	"	0	0	New record sheet
69	12:29	1	"	7	7	
70	12:30	1	"	10	10	
71	12:32	2	"	23.5	11.7	
72	12:33	1	"	11	11	
73	12:34	1	"	10	10	
74	12:35	0	"	0	0	New record sheet
75	12:36	1	"	10	10	
76	12:37	1	"	12	12	
77	12:38	1	"	7	7	
78	12:39	1	"	5	5	
79	12:40	1	"	6	6	New direction
80	12:41	1	"	6	6	
81	12:42	1	"	8.5	8.5	
82	12:43	1	"	7	7	
83	12:44	1	"	8	8	
84	12:45	1	"	6	6	
85	12:46	1	"	7	7	
86	12:47	1	"	7	7	
87	12:50	0	"	0	0	New record sheet
88	12:52	2	"	5	2.5	
89	12:53	1	"	3	3	Rest; began to move, 12:58
90	12:58	0	"	0	0	
91	1:00	2	"	6	3	
92	1:02	2	"	4	2	
93	1:04	2	"	4	2	
94	1:06	2	"	3	1.5	

XXI - (3)

No. of Observation	Time	Time Interval Min.	Temperature Degrees C	Total Distance Mm.	Rate Mm. per Min.	Remarks
95	1:06:30	0	26	0	0	New record sheet
96	1:09	2.5	"	14	5.6	
97	1:11	2	"	17	8.5	
98	1:12	1	"	8	8	
99	1:14	2	"	13	6.5	
						Animal up against edge of slide


XXII

PERFORMANCE RECORD

of

<u>INDIVIDUAL XXII</u>

No. of Observation	Time	Time Interval Min.	Temperature Degrees C	Total Distance Mm.	Rate Mm. per Min.	Remarks
1	9:22	0	24	0	0	
2	9:23	1	"	14	14	Temp. changed, 9:23:30
3	9:24	1	22	6	6	
4	9:25	1	"	3	3	
5	9:26	1	"	5	5	
6	9:27	1	"	8	8	
7	9:28	1	"	10	10	
8	9:29	1	"	8	8	
9	9:30	1	"	8.5	8.5	
10	9:31	1	"	9	9	
11	9:32	1	"	9	9	
12	9:33	1	"	9	9	
13	9:34	1	"	12	12	
14	9:35	0	"	0	0	New record sheet
15	9:36	1	"	12	12	
16	9:37	1	"	8	8	
17	9:38	1	"	12	12	
18	9:39	1	"	7	7	
19	9:40	1	"	9	9	
20	9:41	0	"	0	0	New record sheet
21	9:42	1	"	6	6	
22	9:43	1	"	8	8	
23	9:44	1	"	4	4	
24	9:45	1	"	10	10	
25	9:46	1	"	13	13	
26	9:47	1	"	16	16	
27	9:48	1	"	14	14	
28	9:49	1	"	18	18	
29	9:50	0	"	0	0	New record sheet
30	9:51	1	"	16	16	
31	9:52	1	"	12	12	
32	9:54	2	"	32	16	
33	9:55	1	"	20	20	
						Temp. changed, 9:55:30
34	9:56	0	25	0	0	New record sheet
35	9:57	1	"	18	18	
36	9:58	1	"	18	18	
37	9:59	1	"	20	20	
38	10:00:30	1.5	"	21	14	
39	10:01	0	"	0	0	New record sheet
40	10:02	1	"	11	11	Rest; began to move, 10:04
41	10:05	1	"	8	8	
42	10:06	0	"	0	0	New starting point
43	10:07	1	"	10	10	
44	10:08	1	"	14	14	

XXII - (2)

No. of Observation	Time	Time Interval Min.	Temperature Degrees C	Total Distance Mm.	Rate Mm. per Min.	Remarks
45	10:09	1	25	9	9	
46	10:10	1	"	13	13	
47	10:10:30	0	"	0	0	New record sheet
48	10:12	1.5	"	6	4	
49	10:13	1	"	6	6	
50	10:14	1	"	7	7	
51	10:15	1	"	10	10	
52	10:17	2	"	20	10	
53	10:18	0	"	0	0	New starting point
54	10:19	1	"	15	15	
55	10:20	1	"	15	15	
56	10:21	1	"	15	15	
57	10:22	0	"	0	0	New record sheet
58	10:23	1	"	8	8	
59	10:24	1	"	8	8	
60	10:25	1	"	10	10	
61	10:26	1	"	10	10	
62	10:27	1	"	12	12	
63	10:28	1	"	13	13	
64	10:28:30	0	"	0	0	New record sheet
65	10:30	1.5	"	23	15.3	
66	10:31	1	"	11	11	
67	10:32	1	"	11	11	
68	10:33	1	"	13	13	
69	10:34	1	"	8	8	
70	10:35	1	"	8	8	
71	10:36	1	"	16	16	
72	10:37	1	"	11	11	
73	10:38	1	"	8	8	
74	10:39	0	"	0	0	New record sheet
75	10:41	2	"	25	12.5	
76	10:42	1	"	12	12	
77	10:43	1	"	14	14	
78	10:44	1	"	20	20	
79	10:45	1	"	12	12	
80	10:45:30	0	"	0	0	New record sheet
81	10:47	1.5	"	12	8	
82	10:48	1	"	10	10	
83	10:49	1	"	8	8	
84	10:50	1	"	13	13	
85	10:51	1	"	13	13	
86	10:52	1	"	12	12	
87	10:53	1	"	10	10	
88	10:53:30	0	"	0	0	New record sheet
89	10:55	1.5	"	10	6.66	
90	10:56	1	"	3	3	
91	10:58	2	"	10	5	
92	10:59	0	"	0	0	New record sheet
93	11:00	1	"	14	14	
94	11:01	1	"	11	11	Temp. changed, 11:00:30

No. of Observation	Time	Time Interval Min.	Temperature Degrees C	Total Distance Mm.	Rate Mm. per Min.	Remarks
95	11:02	1	6	3	3	Rest; began to move, 11:07
96	11:08	1	"	6	6	
97	11:10	2	"	3	1.5	
98	11:12	2	"	2	1	

FOLD OUT

PERFORMANCE RECORD
of
[illegible]

No. of Observation	Time	Time Interval Min.	Temperature Degrees C	Total Distance Cm.	Rate Cm. per Min.	Remarks
1	10:[illegible]	[illegible]	22.5	[illegible]	0	
[illegible]	10:57	1	"	5	5	
3	10:58	1	"	7	7	
[illegible]	10:59	1	"	13	13	
[illegible]	11:00	1	"	9	9	
[illegible]	11:01	1	"	6	[illegible]	
[illegible]	11:02	1	"	5	[illegible]	
8	11:03	1	"	6	[illegible]	
9	11:04	1	"	5	6	
[illegible]	11:05	1	"	5	[illegible]	
11	11:06	1	"	6	[illegible]	
12	11:07	1	"	[illegible]	16	Temp. changed,11:07:30
13	11:07:30	0	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	11:08:30	1	"	12	12	
15	11:09:30	1	"	14	14	
16	11:10:30	1	"	9	9	Temp. changed, 11:10:30
17	11:11:30	1	[illegible]	10	10	
18	11:12:30	1	"	5	5	
19	11:13:30	1	"	[illegible]	[illegible]	
[illegible]	11:14:30	1	"	[illegible]	[illegible]	
[illegible]	11:15:30	1	"	5	5	[illegible] 11:16:30
[illegible]	11:17:30	1	"	3	[illegible]	
[illegible]	11:18:30	1	"	[illegible]	[illegible]	
[illegible]	11:19:30	1	"	6	6	
25	11:20:30	1	"	10	10	
[illegible]	11:21	[illegible]	"	0	0	New record sheet
27	11:22	1	"	9	9	
[illegible]	11:23	1	"	5	5	
29	11:24	1	"	7	7	
30	11:25	1	"	5	5	
31	11:26	[illegible]	"	6	6	Rest; begun to move, 11:27
[illegible]	11:28	1	"	[illegible]	[illegible]	
33	11:29	1	"	3	[illegible]	
[illegible]	11:30	1	"	[illegible]	5	
35	11:31	1	"	3	3	
36	11:32:30	1.5	"	6	[illegible]	
37	11:33:30	1	"	[illegible]	7	
38	11:34:30	1	"	3	3	
[illegible]	11:35:30	1	"	[illegible]	6	
40	11:36:30	1	"	11	11	
41	11:38	[illegible]	"	0	0	New record sheet
42	11:39	1	"	7	[illegible]	
43	11:40	1	"	[illegible]	3	

[illegible]

[illegible]	Time	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	11:41	0	20	-	-	Pspd. active;
45	11:42	0	"	-	-	[illegible]
[illegible]	11:43	0	"	0	0	[illegible]
47	11:45	2	"	[illegible]	6	
[illegible]	11:46	1	"	[illegible]	5	[illegible]
49	11:47	1	25	6	6	
50	11:48	1	"	[illegible]	[illegible]	
51	11:49	1	"	6	[illegible]	
52	11:50	1	"	10	10	
53	11:51	1	"	8	8	
54	11:52	1	"	8	[illegible]	
55	11:54	0	"	[illegible]	0	[illegible]
56	11:55	1	"	12	12	
57	11:56	1	"	9	9	
58	11:57	1	"	9	[illegible]	
59	11:58	1	"	12	12	
[illegible]	11:59	1	"	11	11	
61	12:00	1	"	12	12	
[illegible]	12:00:15	0	"	0	0	[illegible]
[illegible]	12:01	.75	"	12	16	
64	12:02	1	"	13	13	
65	12:03	1	"	12	12	
66	12:04	1	"	7	7	
67	12:05	1	"	11	11	
68	12:06	1	"	8	8	Rest; began to move 12:07
[illegible]	12:08	1	"	[illegible]	4	
70	12:09:10	1.17	"	6	5.1	
[illegible]	12:10	[illegible]	"	11	13.4	
72	12:11:10	1	"	14	14	
[illegible]	12:12	.62	"	6	9.7	
[illegible]	12:12:[illegible]	0	"	0	0	[illegible]
75	12:13	.5	"	13	13	
76	12:14	1	"	11	11	
77	12:15	1	"	10	10	
[illegible]	12:16	1	"	11	11	
79	12:17	1	"	17	17	
[illegible]	12:17	0	"	0	0	[illegible]
81	12:18	1	"	17	17	
[illegible]	12:19	1	"	15	[illegible]	
[illegible]	[illegible]	1	"	10	10	
[illegible]	[illegible]	1	"	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	1	"	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible]	-	[illegible]	[illegible]	

[illegible]

[illegible] - (3)

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Remarks
[illegible]	12:26:30	1	[illegible]	10	10	
89	[illegible]	1	"	11	11	
90	12:[illegible]	1	"	5	5	
91	12:29:30	1	"	6	6	
[illegible]	12:30:30	1	"	6	[illegible]	
[illegible]	12:31:30	1	"	5	5	
[illegible]	12:32:30	1	"	11	11	
95	12:33:30	0	"	0	[illegible]	
96	12:34:30	1	"	6	6	
97	12:35:30	1	"	8	[illegible]	
[illegible]	12:36:30	1	"	5	[illegible]	
99a	12:41	0	"	[illegible]	0	
[illegible]	12:42	1	"	10	10	99a - 103a - [illegible]
[illegible]	[illegible]	1	"	9	9	
[illegible]	12:44	1	"	10	10	
[illegible]	[illegible]	1	"	9	9	
[illegible]	[illegible]	0	"	0	0	[illegible]
100	12:48	1	"	10	10	
101	[illegible]	1	"	12	12	
102	12:50	1	"	15	15	
103	12:51	1	"	15	15	
104	12:51:30	0	"	0	[illegible]	[illegible]
105	12:52:30	1	25	[illegible]	[illegible]	Temp. changed, 12:52
106	12:53:30	1	"	[illegible]	6	
109	12:56:30	[illegible]	"	[illegible]	1.3	
110	12:57:30	1	"	13	13	
111	12:58:30	1	"	10	10	
112	12:59:30	1	"	15	15	
113	1:00:30	1.5	"	14	9.3	
114	1:01:30	1	"	19	19	
115	1:02:30	0	"	[illegible]	0	[illegible]
116	1:03:30	1	"	[illegible]	[illegible]	Under debris
						[illegible] 1:03 - 1:31
117	1:33	0	25	0	[illegible]	[illegible]
118	[illegible]	1	"	6	6	
119	1:35	1	"	4	4	
120	1:36	1	"	[illegible]	[illegible]	
121	1:38	2	"	[illegible]	4	[illegible]

[illegible] - [illegible]

[illegible]. of [illegible]	[illegible]	[illegible] Interval [illegible].	Temperature Degrees [illegible]	Total Distance [illegible].	Rate [illegible]. per [illegible].	[illegible]
[illegible]	2:00	0	15	0	0	[illegible]
[illegible]	2:01	1	"	7	7	
[illegible]	2:02	1	"	[illegible]	[illegible]	
125	[illegible]	1	"	6	6	
126	2:04	1	"	[illegible]	[illegible]	
127	2:05	1	"	[illegible]	5	

XXIV

PERFORMANCE RECORD

of

[illegible]

No. of Observation	Time	Time Interval Min.	Temperature Degrees C	[illegible]	[illegible]	Remarks
1	[illegible]	0	[illegible]	0	0	
2	1:46	1	"	[illegible]	[illegible]	
3	[illegible]	1	"	[illegible]	[illegible]	
4	1:48	1	"	3	[illegible]	
5	1:49	1	"	[illegible]	[illegible]	
6	1:50	1	"	6	[illegible]	
7	1:51	1	"	6	[illegible]	
8	1:52	1	"	[illegible]	9	
9	1:53	1	"	12	12	
10	1:54	1	"	[illegible]	[illegible]	
11	1:55	1	"	10	10	
12	1:56	1	"	11	11	
13	1:57	1	"	10	10	
14	1:58	1	"	7	7	
15	1:59	1	"	2	2	
16	2:02	[illegible]	"	0	[illegible]	[illegible]
17	2:03	1	"	[illegible]	[illegible]	
18	[illegible]	1	"	10	10	
19	2:05	1	"	12	12	
20	2:06	1	"	14	14	
21	2:07	1	"	11	11	
22	2:08	1	"	[illegible]	7	
23	2:09	1	"	5	5	
24	2:09:30	0	"	0	0	[illegible]
25	[illegible]	1.5	"	[illegible]	4	
26	2:12	1	"	14	14	
27	2:13	1	"	[illegible]	13	
28	2:14	1	"	3	3	
29	2:15	1	"	12	12	
30	2:16	1	"	11	11	[illegible]
31	2:17	1	20	[illegible]	6	
32	2:18	1	"	5	5	
33	2:20	1	"	[illegible]	11	
34	[illegible]	1	"	[illegible]	9	
35	[illegible]:30	0	"	0	0	[illegible]
36	2:23	1.5	"	12	[illegible]	
37	2:24	1	"	14	[illegible]	
38	2:25	1	"	[illegible]	7	
39	2:26	1	"	7	7	
40	2:27	1	"	3	3	
41	2:28	1	"	2	2	
42	2:29	1	"	[illegible]	[illegible]	
43	2:30	1	"	14	[illegible]	
44	2:31	1	"	13	13	
45	2:31:[illegible]	0	"	0	0	[illegible]
46	2:32:[illegible]	1	"	10	10	
47	2:33:[illegible]	1	"	5	[illegible]	

XXV

[illegible]

[illegible]

of

[illegible]

No. of Observation	Time	Time Interval Min.	Temperature Degrees C	Total Distance Cm.	Rate Cm. per min.	Remarks
1	2:50:15	0	20	0	0	
2	2:51:15	1	"	10	10	
3	2:52:15	1	"	10	10	
[illegible]	2:53:15	1	"	7	[illegible]	
5	2:54:15	1	"	8	8	
[illegible]	2:55:15	1	"	10	[illegible]	
7	2:56:15	1	"	[illegible]	[illegible]	
8	2:57:15	1	"	7	7	
9	2:58:15	1	"	6	6	
10	2:59:15	1	"	7	[illegible]	
11	3:00:15	1	19	6	[illegible]	Temp. changed, 3:00
12	3:01:15	1	17	7	7	
13	3:02:15	1	"	7	7	
14	3:03:15	1	"	7	7	
15	3:04:15	1	"	[illegible]	[illegible]	
16	3:04:45	0	"	0	0	[illegible]
17	3:05:45	1	"	12	12	
18	3:06:45	1	"	6	6	
19	3:07:45	1	"	7	7	
20	3:08:45	1	"	13	13	
21	3:09:45	1	"	9	[illegible]	
[illegible]	3:10:45	1	"	[illegible]	4	
[illegible]	3:11:45	1	"	4	4	
[illegible]	3:12:45	1	"	[illegible]	[illegible]	
25	3:13:45	1	"	10	10	
26	3:14:45	1	"	3.5	3.5	
27	3:15:45	1	"	9	9	
[illegible]	3:16:30	0	"	0	0	
29	3:17:30	1	"	7	7	
30	3:18:30	[illegible]	"	5	5	
31	3:19:30	1	"	6	[illegible]	
32	[illegible]	1	"	[illegible]	6	
33	3:21:30	1	"	[illegible]	[illegible]	
[illegible]	3:22:30	1	"	5	5	[illegible]
35	3:24:30	0	"	[illegible]	[illegible]	
36	3:26:30	[illegible]	"	[illegible]	3.5	
37	3:28:15	0	"	0	0	[illegible]
38	3:29:30	1.2	"	[illegible]	[illegible]	
[illegible]	3:30:30	1	"	3	3	
[illegible]	3:31:30	[illegible]	"	[illegible]	[illegible]	
41	3:32:30	[illegible]	"	[illegible]	2	
						Rest; began to move, 3:37
						[illegible]

[illegible] - (1)

No. of [illegible]	[illegible]	[illegible] [illegible] [illegible]	[illegible] [illegible] C	[illegible] [illegible] [illegible]	[illegible] [illegible] [illegible]	[illegible]
[illegible]	[illegible]	0	16	[illegible]	0	
[illegible]	[illegible]	[illegible]	"	3	1	
44	3:50	[illegible]	"	[illegible]	0.2	
45	4:06	16	"	3	0.2	

FOLD OUT

PERFORMANCE RECORD

of

[illegible]

No. of Observation	Time	Time Interval min.	Temperature Degrees C	Total Distance cm.	Rate cm. per min.	Remarks
1	1:11	0	21	0	0	
[illegible]	1:12	1	"	3	3	
[illegible]	1:13	1	"	3	[illegible]	
[illegible]	1:14	1	"	5	5	[illegible] 1:17
[illegible]	1:18	1	"	5	5	
[illegible]	1:19	1	"	5	5	
7	1:20	1	"	5	5	
[illegible]	1:21	1	"	[illegible]	6	
[illegible]	1:22	1	"	[illegible]	7	
10	1:23	1	"	[illegible]	7	
11	1:23:30	[illegible]	"	[illegible]	0	[illegible]
12	1:24:30	1	"	[illegible]	4	
[illegible]	1:25:30	1	"	10	10	
14	[illegible]	1	"	12	12	
15	1:27:30	1	"	[illegible]	9	
16	1:28:30	1	"	[illegible]	4	
17	1:29:30	1	"	12	12	
18	1:30:30	[illegible]	"	12	12	
19	1:31	[illegible]	"	0	[illegible]	[illegible]
[illegible]	1:32	1	"	9	[illegible]	
[illegible]	1:33	1	"	7	7	
[illegible]	[illegible]	1	"	[illegible]	9	
23	1:35	1	"	9	[illegible]	
[illegible]	[illegible]	1	"	10	10	
25	1:37	1	"	12	12	
[illegible]	1:38	1	"	[illegible]	9	
[illegible]	1:39	[illegible]	"	7	7	
[illegible]	1:40	[illegible]	"	0	0	[illegible]
29	1:41	1	"	[illegible]	7	
30	1:42	1	"	8	8	[illegible]
31	1:43	1	[illegible]	5	5	
32	1:44	1	"	5	5	
33	1:45	1	"	5	5	
[illegible]	1:46	1	"	5	5	
35	1:47	1	"	4	4	
[illegible]	1:48	1	"	13	13	
[illegible]	[illegible]	[illegible]	"	9	9	
[illegible]	1:50	[illegible]	"	5	[illegible]	
39	1:51	1	"	7	7	
[illegible]	1:52	1	"	7	7	
[illegible]	1:53	1	"	6	[illegible]	
[illegible]	1:54	1	"	3	3	
[illegible]	1:55	[illegible]	"	[illegible]	[illegible]	
[illegible]	1:56	[illegible]	"	0	0	[illegible]
[illegible]	[illegible]	[illegible]	"	3	7	
[illegible]	[illegible]	[illegible]	"	[illegible]	[illegible]	
47	[illegible]	[illegible]	"	[illegible]	[illegible]	[illegible]

[illegible]	2:01	1	[illegible]	[illegible]	[illegible]	
[illegible]	2:02	1	"	[illegible]	[illegible]	
50	[illegible]	1	"	[illegible]	3	
51	[illegible]	1	"	3	[illegible]	
52	2:05	1	"	[illegible]	[illegible]	
53	2:06	1	"	[illegible]	[illegible]	
[illegible]	2:07	1	"	[illegible]	[illegible]	
55	2:08	1	"	5	[illegible]	
56	[illegible]	1	"	[illegible]	3	
57	2:10	1	"	[illegible]	[illegible]	
58	2:11	1	"	6	[illegible]	
59	2:12	1	"	2	[illegible]	
[illegible]	2:13	1	"	[illegible]	2	
61	2:14:15	1.25	"	3	2.4	
[illegible]	2:15	.75	"	[illegible]	10.7	
63	2:16	1	"	12	12	
[illegible]	2:16:35	[illegible]	"	0	0	[illegible]
65	2:17:35	[illegible]	"	9	[illegible]	
66	2:18:35	1	"	5	5	[illegible] 2:19:35
[illegible]	2:20:35	1	26.5	5	5	
[illegible]	2:21:35	1	"	[illegible]	[illegible]	
70	2:22:35	1	"	[illegible]	9	
71	2:23:35	1	"	5	5	
72	2:24:35	1	"	5	5	[illegible] 2:25:35
[illegible]	2:26:35	1	"	6	[illegible]	
74	2:27:35	1	"	[illegible]	[illegible]	
75	2:28:35	[illegible]	"	5	5	
76	2:29:35	1	"	[illegible]	7	
77	2:30:35	1	"	4	4	
78	2:31:35	1	"	4	4	
79	2:32:35	1	"	5	5	
80	2:33:35	1	"	[illegible]	[illegible]	
81	2:34:35	[illegible]	"	6	[illegible]	
[illegible]	2:35:35	[illegible]	"	6	6	
[illegible]	2:36:35	1	"	10	10	
[illegible]	2:37	[illegible]	"	0	[illegible]	[illegible]
85	2:38	[illegible]	"	[illegible]	2	[illegible] 2:40
86	2:41	[illegible]	"	[illegible]	3	[illegible] 2:43
87	[illegible]	[illegible]	"	[illegible]	4	
[illegible]	2:45	1	[illegible]	[illegible]	2	[illegible]
[illegible]	2:49:30	4.5	"	5	1.1	
90	[illegible]	1	"	[illegible]	2	

[illegible] (6)

No. of Observation	Time	Time Interval Min.	Temperature Degrees C	Total Distance Cm.	Rate Cm. per Min.	Remarks
91	2:51:30	1	23	[illegible]	[illegible]	
92	2:52:30	1	"	[illegible]	[illegible]	
[illegible]	2:53:30	1	"	3	3	
[illegible]	2:54:30	1	"	[illegible]	[illegible]	
95	2:55:30	1	"	4	4	
96	2:56:30	[illegible]	"	0	0	[illegible]
97	2:57:30	[illegible]	"	[illegible]	3	
98	2:58:30	1	"	[illegible]	3	
99	2:59:30	1	"	[illegible]	[illegible]	
						Temp. changed, 2:59:30
100	[illegible]	2.5	19	8	3.2	
101	3:03	1	"	[illegible]	3	
102	3:04	1	"	[illegible]	[illegible]	
103	3:05	[illegible]	"	[illegible]	3	
[illegible]	3:06	1	"	3	[illegible]	
105	3:09	3	"	9	3	
106	3:11	[illegible]	"	5	2.5	
107	3:15	4	"	7	1.8	
108	3:18	3	"	[illegible]	0.6	
109	3:25	7	"	2	0.3	
110	3:27	2	"	3	1.5	
111	3:30	[illegible]	"	[illegible]	1.3	
112	3:31	1	"	[illegible]	4	
113	3:32	1	"	[illegible]	4	
114	3:33	1	"	5	5	Temp. changed, 3:33
115	3:34:30	0	20	0	[illegible]	[illegible]
116	3:35:30	1	"	5	5	
117	3:36:30	1	"	5	5	
118	3:37:30	1	"	5	5	
119	3:38:30	[illegible]	"	5	5	
120	3:39:30	1	"	[illegible]	3	
121	3:41:30	[illegible]	"	[illegible]	4.5	


XXVII

[illegible]
of
[illegible]

1	10:30	0	22.5	0	0	
[illegible]	10:31	1	"	[illegible]	[illegible]	[illegible]
[illegible]	10:32	1	21	6	6	
[illegible]	10:33	1	"	6	[illegible]	
5	10:34	1	"	8	[illegible]	
[illegible]	10:35	1	"	5	[illegible]	
7	10:36	1	"	3	3	
8	10:37:15	1.25	"	3	[illegible]	
9	10:38	.75	"	[illegible]	4	
10	10:39	1	"	7	7	
11	10:40	1	"	8	[illegible]	
12	10:41	1	"	10	10	
13	10:42	1	"	10	10	
[illegible]	10:42:30	[illegible]	"	0	0	[illegible]
[illegible]	10:43:30	1	"	7	7	
[illegible]	10:44:30	1	"	10	10	
17	10:45:30	1	"	[illegible]	6	
18	10:46:30	1	"	10	10	
19	10:47:30	1	"	8	[illegible]	
20	10:48:30	[illegible]	"	7	[illegible]	
21	10:49:30	1	"	[illegible]	5	
[illegible]	10:50:30	1	"	[illegible]	[illegible]	
[illegible]	10:51:30	1	"	5	5	
[illegible]	10:52:30	1	"	10	10	
25	10:53:30	1	"	10	10	
[illegible]	10:54	0	"	0	0	[illegible]
27	10:55	1	"	9	[illegible]	
28	10:56	1	"	4	[illegible]	
29	[illegible]	1	"	5	5	[illegible]
30	10:58:45	0	"	0	[illegible]	
31	10:59:45	1	"	5	5	
32	11:00:45	1	"	10	10	
33	11:01:45	1	"	8	[illegible]	
34	11:03	[illegible]	"	0	0	[illegible]
35	11:04	1	"	11	11	Temp. changed, 11:03:30
36	11:05	[illegible]	12	[illegible]	[illegible]	**To 12^{0} for 1.5 minutes**
37	11:06	1	15	[illegible]	[illegible]	
38	11:08	0	"	[illegible]	0	[illegible]
						[illegible] 11:12
39	11:12	[illegible]	"	[illegible]	[illegible]	

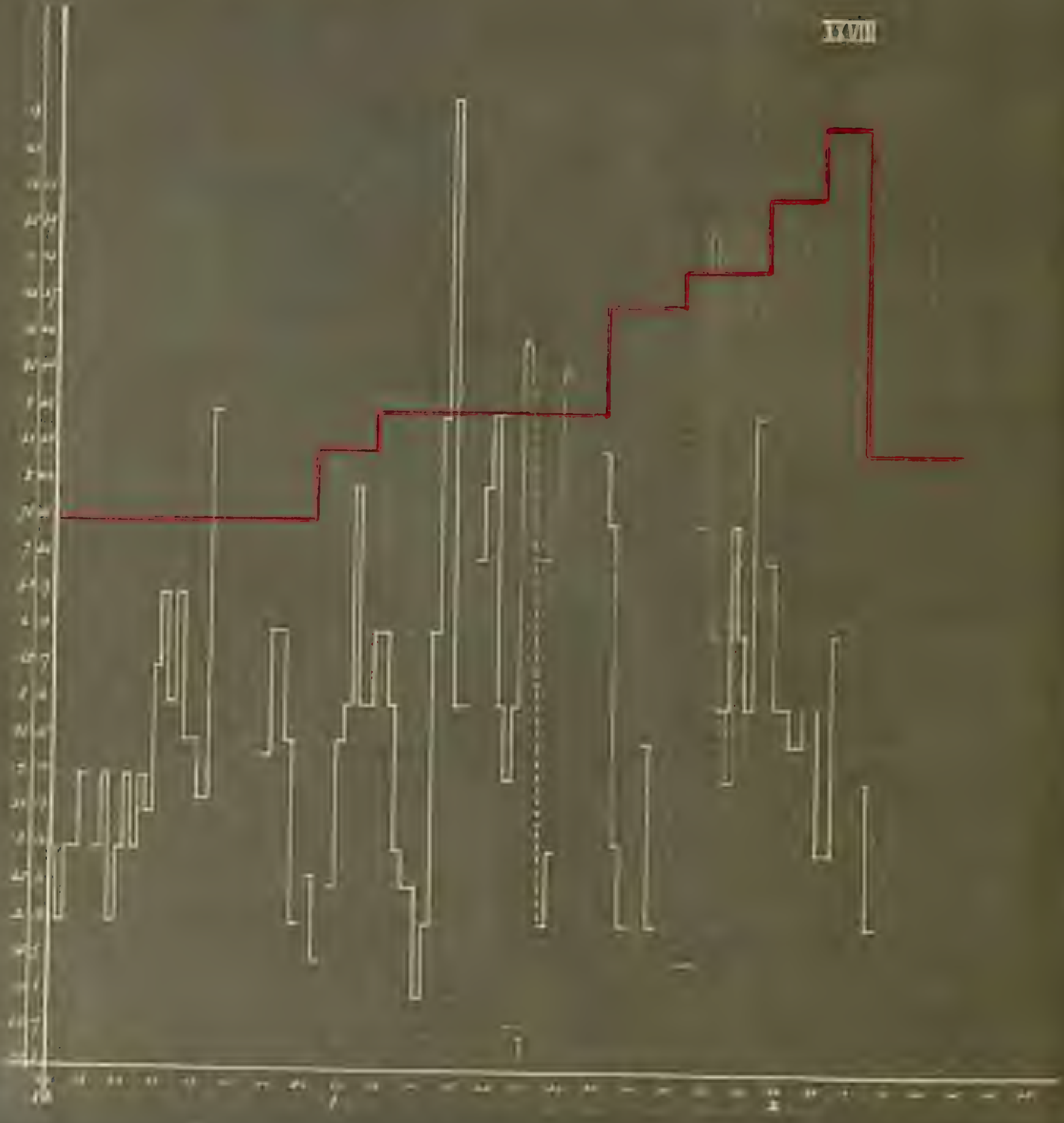
No. of Observation	Time	Time Interval Min.	Temperature	Total Distance	Rate	Remarks
[illegible]	11:13	1	[illegible]	3	3	
41	11:14	1	"	5	5	
[illegible]	11:15	[illegible]	"	[illegible]	[illegible]	
43	11:16	[illegible]	"	0	0	[illegible]
44	11:17	0	"	0	0	Brief rest
[illegible]	11:18	1	"	[illegible]	4	
46	11:19	1	"	4	4	[illegible]
47	11:22	0	"	0	0	Attached again
[illegible]	11:23	1	"	[illegible]	[illegible]	
49	[illegible]	1	"	5	5	
50	11:25	0	"	0	[illegible]	New record sheet
51	11:26	1	"	7	7	Floating
[illegible]	11:28	[illegible]	"	0	[illegible]	[illegible]
53	11:29	1	"	5	5	
54	11:30	1	"	[illegible]	[illegible]	
55	11:31	1	"	10	10	
56	11:32	1	"	3	5	Temp. changed, 11:32
57	11:33	1	[illegible]	[illegible]	[illegible]	

Individual [illegible]

7a	10:36	0	21	0	0	
[illegible]	10:37:15	1.25	"	6.5	5.2	
[illegible]	10:38	.75	"	5	7	
10a	10:39	1	"	6.5	6.5	
[illegible]	10:40	1	"	7	7	
12a	10:41	1	"	4	[illegible]	
13a	10:42	1	"	6	[illegible]	
[illegible]	10:42:30	0	"	0	0	[illegible]
15a	10:43:30	1	"	9	9	
16a	10:44	0.5	"	[illegible]	12	
17a	10:45	[illegible]	"	[illegible]	[illegible]	
18a	10:46	[illegible]	"	[illegible]	[illegible]	
19a	10:47	[illegible]	"	5	5	
[illegible]	10:48	[illegible]	"	15	15	
[illegible]	10:49	[illegible]	"	10	10	
[illegible]	10:50	[illegible]	"	7	7	
[illegible]	10:51	[illegible]	"	15	15	
24a	10:52	[illegible]	"	10	10	
[illegible]	10:53	[illegible]	"	[illegible]	8	
[illegible]	10:54	[illegible]	"	0	0	New record sheet
27a	10:55	[illegible]	[illegible]	[illegible]	7	
[illegible]	10:56	1	"	[illegible]	[illegible]	
[illegible]	10:57	[illegible]	"	[illegible]	[illegible]	

[illegible]	10:58	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	10:59	1	"	[illegible]	10	
[illegible]	11:00	1	"	[illegible]		
[illegible]	[illegible]		"	[illegible]	7	

XXVIII



PERFORMANCE RECORD

of

<u>INDIVIDUAL XXVIII</u>

No. of Observation	Time	Time Interval Min.	Temperature Degrees C	Total Distance Mm.	Rate Mm. per Min.	Remarks
1	12:20	0	21	0	0	
2	12:21	1	"	3	3	
3	12:22	1	"	2	2	
4	12:24	2	"	6	3	
5	12:25	1	"	4	4	
6	12:26	0	"	0	0	New record sheet
7	12:27	1	"	3	3	
8	12:28	1	"	4	4	
9	12:29	1	"	2	2	
10	12:30	1	"	3	3	
11	12:31	1	"	4	4	
12	12:32	1	"	3	3	
13	12:33	1	"	4	4	
14	12:34	1	"	3.5	3.5	
15	12:35	1	"	5.5	5.5	
16	12:36	1	"	6.5	6.5	
17	12:37	1	"	5	5	
18	12:38	1	"	6.5	6.5	
19	12:39	1	"	4.5	4.5	
20	12:40	1	"	4.5	4.5	
21	12:41:30	1.5	"	5.5	3.7	
22	12:43	1.5	"	9	6	Observations interrupt
23	12:48:30	0	"	0	0	New record sheet
24	12:50	1.5	"	6.5	4.3	
25	12:51	1	"	6	6	
26	12:52	1	"	6	6	
27	12:53	1	"	4.5	4.5	
28	12:54	1	"	2	2	
29	12:55:15	0	"	0	0	New record sheet Temp. changed, 12:55:3
30	12:56	.75	23	2	2.66	
31	12:57	1	"	1.5	1.5	
32	12:58	0	"	0	0	New starting point
33	12:59	1	"	2.5	2.5	
34	1:00	1	"	4.5	4.5	
35	1:01	1	"	5	5	
36	1:02	1	"	8	8	
37	1:03	1	"	5	5	Temp. changed, 1:03:30
38	1:04	1	24	5	5	
39	1:05	1	"	6	6	
40	1:06	1	"	6	6	
41	1:07	1	"	5	5	
42	1:08	1	"	3	3	
43	1:10	2	"	5	2.5	
44	1:11	1	"	1	1	
45	1:12	1	"	2	2	
46	1:13	1	"	6	6	

XXVIII - (2)

No. of Observation	Time	Time Interval Min.	Temperature Degrees C	Total Distance Mm.	Rate Mm. per Min.	Remarks
47	1:14:15	1.25	24	11	8.8	
48	1:15	.75	"	10	13.3	
49	1:16	1	"	5	5	
50	1:17	1	"	5	5	
51	1:18	0	"	0	0	New record sheet
52	1:19	1	"	7	7	
53	1:20	1	"	8	8	
54	1:21	1	"	9	9	
55	1:22	1	"	5	5	
56	1:23	1	"	4	4	
57	1:24	1	"	5	5	
58	1:25	1	"	10	10	A second individual in field; shown in graph in dotted lines
						Rest; began to move, 1:27
59	1:28	1	"	2	2	
60	1:29	1	"	3	3	
61	1:31	0	"	0	0	Animal floating
62	1:33	0	"	0	0	" "
63	1:35	0	"	0	0	New record sheet
						Temp. changed, 1:35:30
64	1:36	1	27	8.5	8.5	
65	1:37	1	"	7.5	7.5	
66	1:38:10	1.16	"	5	3.1	
67	1:39:10	1	"	2	2	Rest; began to move, 1:41
68	1:41	0	"	0	0	New starting point
69	1:42	1	"	4.5	4.5	
70	1:43:30	1.5	"	3	2	
71	1:44:30	0	"	0	0	New record sheet
72	1:46	0	28	0	0	Animal floating
73	1:48	0	"	0	0	" "
74	1:49	0	"	0	0	" "
75	1:51	0	"	0	0	New starting point
76	1:52	1	"	5	5	
77	1:53	1	"	5	5	
78	1:54	1	"	7.5	7.5	
79	1:55	1	"	6	6	
80	1:56	1	"	5	5	
81	1:57	1	"	9	9	Temp. changed, 1:57:30
82	1:57:30	0	30	0	0	New record sheet

XXVIII - (3)

No. of Observation	Time	Time Interval Min.	Temperature Degrees C	Total Distance Mm.	Rate Mm. per Min.	Remarks
83	1:59	1.5	30	10	7	
84	2:00	1	"	5	5	
85	2:01	1	"	5	5	
86	2:03	2	"	9	4.5	Temp. changed, 2:04:30
87	2:05	2	32	10	5	
88	2:07	2	"	6	3	
89	2:08	1	"	6	6	Observations interrupted
						Temp. changed, 2:11:30
91	2:11	0	23	0	0	New record sheet
92	2:12	1	"	4	4	
93	2:13	1	"	2	2	

Individual XXVIIIa *

No. of Observation	Time	Time Interval Min.	Temperature Degrees C	Total Distance Mm.	Rate Mm. per Min.	Remarks
1	1:27:20	0	24	0	0	Probably divided, 1:27
2	1:28:20	1	"	7	7	
3	1:29:45	1.4	"	11	7.8	
4	1:31	1.25	"	12	9.6	
5	1:48:30	0	28	0	0	
6	1:49:30	1	"	7.5	7.5	
7	1:50:30	1	"	11.5	11.5	
8	1:51:30	1	"	6	6	
9	1:52:30	1	"	5	5	
10	1:53:30	1	"	4	4	
11	1:54:30	1	"	7	7	

*Graph on same Plate with Individual XXIX


XXIX


XXVII

PERFORMANCE RECORD
of
[illegible]

No. of Observation	Time	Time Interval Min.	Temperature Degrees F	[illegible] mm.	Rate [illegible]	Remarks
1	[illegible]	0	21	0	0	
[illegible]	2:49	1	"	[illegible]	[illegible]	
[illegible]	2:51	[illegible]	"	5	2.5	
[illegible]	2:53	[illegible]	"	11	5.5	
5	2:55	2	"	15	7.5	
[illegible]	2:57	2	"	12.5	6.2	
[illegible]	2:59	2	"	6	3	
8	3:01	2	"	[illegible]	1.5	[illegible]
9	3:07	0	"	0	0	[illegible]
10	3:08	1	"	6.5	6.5	[illegible]
						[illegible]
11	3:09	1	[illegible]	3	[illegible]	
[illegible]	3:10	1	"	[illegible]	4	
13	3:12	2	"	[illegible]	2	
[illegible]	3:13	1	"	[illegible]	[illegible]	
15	3:15	[illegible]	"	6	3	
16	3:18	[illegible]	"	6	2	
17	3:20	2	"	4	[illegible]	[illegible]

FOLD OUT

PERFORMANCE RECORD
of
INDIVIDUAL [illegible]

No. of Observation	Time	Time Interval Min.	Temperature [illegible] C	[illegible] Distance In.	[illegible] In. per Min.	Remarks
1	[illegible]	[illegible]	20	[illegible]	0	
[illegible]	[illegible]	1	"	6	6	
[illegible]	9:05	1	"	5	5	
[illegible]	9:07	[illegible]	"	6	[illegible]	
[illegible]	9:08	1	"	[illegible]	9	
6	9:09	1	"	10	10	
[illegible]	9:10	1	"	[illegible]	4	
8	9:11	1	"	3	3	
[illegible]	9:12	1	"	[illegible]	[illegible]	
10	9:12:30	[illegible]	"	0	0	[illegible]
11	9:13:30	1	"	13	13	
12	9:14:30	1	"	[illegible]	[illegible]	
13	9:15:30	[illegible]	"	10	10	
[illegible]	9:16:30	1	"	[illegible]	9	
15	9:17:30	1	"	9	[illegible]	
16	9:18:30	1	"	8	[illegible]	
17	9:19:30	1	"	7	7	
18	9:20:30	1	"	8	8	
19	9:21:30	1	"	[illegible]	[illegible]	
20	[illegible]	1	"	7	7	
21	9:23:30	1	"	[illegible]	2	
22	[illegible]	[illegible]	"	0	0	New record sheet
[illegible]	9:25	1	"	1.5	1.5	[illegible]
25	9:29	1	"	[illegible]	3	
[illegible]	9:30	1	"	[illegible]	2	
27	9:31	1	"	[illegible]	[illegible]	
28	9:32	1	"	4.[illegible]	4.5	
[illegible]	[illegible]	2	"	13	6.5	
[illegible]	9:35	1	Variable	[illegible]	[illegible]	Temp. changed, 9:35
31	9:36	1	25	[illegible]	[illegible]	
32	9:37	[illegible]	"	0	0	New record sheet
33	9:40	0	"	0	0	Observation interrupted
34	9:41	1	"	3.5	3.5	
35	9:42	1	"	3.5	3.5	
36	9:43	1	"	[illegible]	[illegible]	
37	9:47	[illegible]	"	[illegible]	5.7	
[illegible]	9:48	1	"	[illegible]	[illegible]	
39	9:49	1	"	5	[illegible]	
40	9:50	0	"	0	0	New record sheet
41	9:51	1	"	[illegible]	3	
[illegible]	9:52	1	"	[illegible]	[illegible]	
43	9:53	1	"	[illegible]	3	
[illegible]	9:55	[illegible]	"	4	[illegible]	
45	9:57	2	"	[illegible]	2	
[illegible]	9:59	2	"	2	1	
[illegible]	10:01	[illegible]	"	[illegible]		

[illegible] - [illegible]

No. of Observation	Time	Time Interval Min.	Temperature Degrees C.	Total Contacts No.	Rate No. per Min.	Remarks
[illegible]	10:03	[illegible]	25	16	8	
[illegible]	10:04	1	"	9	9	
50	10:05	1	"	10	10	
51	10:07	[illegible]	"	10	5	Temp. changed, 10:08
52	10:09	[illegible]	Variable	12	[illegible]	
53	10:10	[illegible]	27.5	[illegible]	[illegible]	[illegible]
54	10:12	[illegible]	"	[illegible]	[illegible]	
55	10:14	[illegible]	"	9	4.5	
56	10:16	2	"	12	6	
57	10:18	[illegible]	"	15	7.5	
58	10:20	[illegible]	"	20	10	
59	10:21	1	"	11	11	
60	10:22	[illegible]	"	0	0	New record sheet
61	[illegible]	[illegible]	"	20	10	[illegible]
[illegible]	10:25	1	[illegible]	13	13	
63	10:26	1	"	4	4	
[illegible]	10:27	1	"	5	5	
65	10:28	1	"	13	13	
66	10:30	2	"	18	9	
67	10:32	[illegible]	"	20	10	
68	10:34	[illegible]	"	[illegible]	11.5	
69	10:35	1	"	16	[illegible]	
70	[illegible]	1	"	11	11	
71	10:37	0	"	0	0	[illegible]
72	10:38	1	"	11.5	11.5	
73	10:39	1	"	13	13	
74	10:40	1	"	13	13	[illegible]
75	10:41	[illegible]	20	13	13	
[illegible]	10:42	[illegible]	"	13	13	
77	[illegible]	[illegible]	"	11.5	5.7	
[illegible]	[illegible]	[illegible]	"	13.5	6.7	
[illegible]	[illegible]	[illegible]	"	12	[illegible]	
[illegible]	10:50	[illegible]	"	[illegible]	[illegible]	
81	10:51	[illegible]	"	[illegible]	[illegible]	
[illegible]	10:52	0	"	0	[illegible]	[illegible]
[illegible]	10:55	5	"	7.5	1.5	
[illegible]	10:57	[illegible]	"	15	7.5	[illegible]
[illegible]	10:58	[illegible]	16	[illegible]	[illegible]	
[illegible]	10:59	[illegible]	[illegible]	[illegible]	[illegible]	

XXX - (3)

No. of Observation	Time	Time Interval Min.	Temperature Degrees C	Total Distance Mm.	Rate Mm. per Min.	Remarks
87	11:00	1	15	3	3	
88	11:02	0	"	0	0	New record sheet
89	11:04	2	"	5	2.5	
90	11:06	2	"	11	5.5	
91	11:07	1	"	10	10	
92	11:08	1	"	5	5	
93	11:09	0	"	0	0	New record sheet
94	11:11	2	"	10	5	
95	11:13	2	"	11	5.5	
96	11:17	4	"	20	5	
97	11:19	2	"	10	5	
98	11:21	2	"	10	5	
99	11:22	0	"	0	0	New record sheet
100	11:24	2	"	9	4.5	
101	11:26	2	"	7	3.5	
102	11:28	2	"	12.5	6.25	
103	11:30	2	"	11	5.5	
104	11:32	2	"	10	5	Temp. changed, 11:32:3
105	11:33	1	27	6	6	
106	11:34	1	"	8	8	
107	11:35	1	"	4	4	Rest; began to move, 11:36
108	11:36	0	"	0	0	New record sheet
109	11:38	2	"	2	1	
110	11:40	2	"	4	2	
111	11:43	3	"	4	1.3	
112	11:45	2	"	2	1	

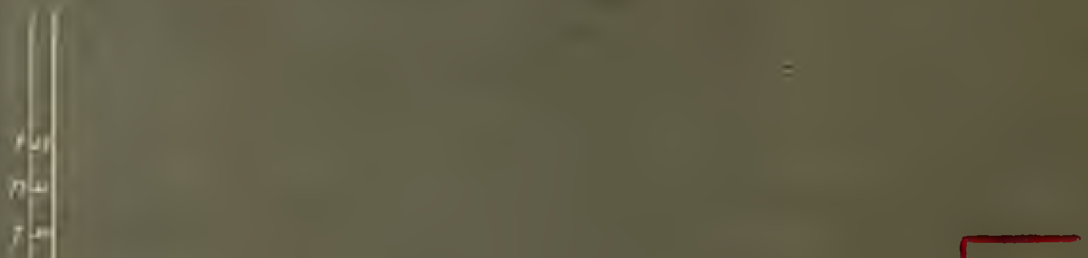
FOLD OUT

PERFORMANCE RECORD

of

INDIVIDUAL XXXI

No. of Observation	Time	Time Interval Min.	Temperature Degrees C	Total Distance Mm.	Rate Mm. per Min.	Remarks
1	8:50	0	20	0	0	
2	8:51	1	"	4.5	4.5	
3	8:53	2	"	7	3.5	
4	8:54	1	"	3	3	
5	8:55	1	"	3	3	
6	8:57	2	"	10	5	
7	8:58	1	"	3	3	
8	8:59	1	"	4	4	
9	9:00	1	"	6	6	
10	9:01	1	"	10	10	
11	9:02	0	"	0	0	New record sheet
12	9:03	1	"	3	3	
13	9:06	3	"	5	1.7	
14	9:08	2	"	3	1.5	Changing direction
15	9:10	2	"	14	7	
16	9:12	2	"	8	4	Rest until 9:14:20; observations began, 9:15
17	9:15	0	"	0	0	
18	9:16	1	"	3.5	3.5	
19	9:17	1	"	4	4	
20	9:18	1	"	3	3	
21	9:19	1	"	2	2	
22	9:20	1	"	2	2	
23	9:23	3	"	8	2.7	
						Temp. changed, 9:23:30 to 28^{0}
						At 9:28, temp. 29^{0} - animal rosette-shaped
						Temp. changed, 10:24:30
						No locomotion, 9:23 to 9:35
						Observations began, 10:45
31	10:45	0	20	0	0	
32	10:46	1	"	6	6	
33	10:48	2	"	7.5	3.7	
34	10:49	1	"	3	3	
35	10:50	1	"	3	3	
36	10:51	1	"	3	3	
37	10:53	2	"	3	1.5	
38	10:55	2	"	6	3	
39	10:56	1	"	5	5	Temp. changed, 10:56


XXXII

PERFORMANCE RECORD

of

INDIVIDUAL XXXII

No. of Observation	Time	Time Interval Min.	Temperature Degrees C	Total Distance Mm.	Rate Mm. per Min.	Remarks
1	11:59	0	16	0	0	
2	12:00	1	15	3	3	
3	12:02	2	14	4	2	
4	12:04	2	"	2	1	
5	12:06	2	"	3	1.5	
6	12:08	2	"	8	4	
7	12:11	3	"	11	3.7	
8	12:14	3	"	7	2.3	
9	12:17	3	"	6	2	
10	12:20	3	"	7	2.3	
11	12:24	4	"	5	1.2	
12	12:27	3	"	7	2.3	
13	12:30	3	"	13	4.3	
14	12:30:30	0	"	0	0	New record sheet
						Temp. changed, 12:30:30
15	12:32	1.5	6	3	2	
16	12:35	3	"	4	1.3	
17	12:39	4	"	4	1	
18	12:42	0	"	0	0	New record sheet
19	12:52	10	"	5	0.2	
20	12:57	5	"	3	0.6	
21	1:02	5	"	2	0.4	Temp. changed, 1:03
22	1:04	0	12	0	0	
						Rest; began to move, 1:30
23	1:34	4	"	4	1	
						Temp. changed, 1:37
24	1:38	4	20	4	1	
25	1:40	2	"	4	2	
26	1:42	2	"	10	5	
						Under debris until 1:56

PERFORMANCE RECORD
of
[illegible]

No. of Observation	Time	Time Elapsed Min.	[illegible] Degrees	Total Distance Cm.	Dist. per Min. Cm.	Remarks
1	[illegible]:18	[illegible]	20	0	0	
[illegible]	[illegible]	[illegible]	"	8.5	[illegible].1	
[illegible]	[illegible]	[illegible]	"	12	3	
[illegible]	[illegible]	[illegible]	"	15	5	
5	2:33	[illegible]	"	16	4	
[illegible]	[illegible]	1	"	5	5	
7	[illegible]	[illegible]	"	0	0	New record sheet
8	2:36	1.5	"	7	5	
[illegible]	[illegible]	2	"	10	5	
10	2:40	[illegible]	"	3	1.5	
11	2:42	[illegible]	"	[illegible]	3	
12	[illegible]	2	"	[illegible]	[illegible]	
13	2:46	2	"	[illegible]	3	
14	2:48	2	"	6	3	[illegible]
15	[illegible]:49	[illegible]	25	12	12	
16	2:51	2	26	[illegible]	11.5	
17	2:53	2	"	[illegible]	10	
18	2:53:45	0	"	0	0	New record sheet
19	2:55	1.25	"	[illegible]	3.2	
20	2:57	[illegible]	"	13	6.5	
[illegible]	[illegible]	2	"	25	12.5	

[illegible]
of
[illegible] *

[illegible]	[illegible]	[illegible] Min.	[illegible]	[illegible] Distance [illegible]	[illegible] Min.	[illegible]
1	[illegible]	0	26	0	0	
[illegible]	3:03	1.25	"	7	5.6	
[illegible]	3:05	2	"	20	10	
[illegible]	3:07	[illegible]	"	13	6.5	
5	3:08	1	"	[illegible]	[illegible]	
6	3:10	[illegible]	"	[illegible]	4	
7	[illegible]	0	"	0	[illegible]	[illegible]
[illegible]	3:12	1	"	4	4	
[illegible]	3:14	[illegible]	"	9	[illegible]	
10	3:15	1	"	[illegible]	[illegible]	
11	3:17	2	"	15	7.5	
12	[illegible]	1	"	9	[illegible]	
13	3:19	1	"	[illegible]	[illegible]	
14	3:20:20	1.[illegible]	"	[illegible]	5.26	[illegible] of slide

*Graph on same Plate with Individual XXXIII.

FOLD OUT

PERFORMANCE RECORD
OF
[illegible]

No. of Observation	Time	Time Interval Min.	[illegible] Degrees	Total Distance Cm.	Rate Cm. per Min.	Remarks
1	12:13	0	22	[illegible]	0	
2	12:14	1	"	8.5	8.5	
3	[illegible]	1	"	[illegible]	[illegible]	
4	12:16	1	"	[illegible]	[illegible]	
5	[illegible]	1	"	[illegible]	[illegible]	
6	12:18	1	"	[illegible]	[illegible]	
7	[illegible]	1	"	7	7	
8	[illegible]	1	"	[illegible]	[illegible]	
9	[illegible]	[illegible]	"	[illegible]	[illegible]	[illegible]
10	12:22	1	"	9.5	[illegible]	
11	12:23	1	"	6.5	[illegible]	
12	12:24	1	"	9	[illegible]	
13	12:25	1	"	7.5	7.5	
14	12:26	1	"	[illegible]	[illegible]	
15	12:27	1	"	7	7	
16	[illegible]	1	"	[illegible]	[illegible]	
17	12:29	1	"	[illegible]	[illegible]	
18	12:30	1	"	[illegible]	[illegible]	
19	12:31	0	"	0	0	[illegible]
20	12:32	1	"	6.5	6.5	
21	12:33	1	"	[illegible]	[illegible]	
22	[illegible]	1	"	8.5	8.5	
23	12:35	1	"	[illegible]	[illegible]	
24	12:36	1	"	[illegible]	[illegible]	
25	12:37	1	"	[illegible]	[illegible]	
26	[illegible]	1	"	10	10	
27	[illegible]	1	"	[illegible]	[illegible]	
28	12:40	1	"	5	5	
29	12:41	1	"	[illegible]	[illegible]	
30	[illegible]	1	"	[illegible]	[illegible]	
31	12:43	1	"	[illegible]	[illegible]	
32	12:44	0	"	0	0	[illegible]
33	12:45	1	"	[illegible]	[illegible]	
34	[illegible]	1	"	5	5	
35	[illegible]	1	"	[illegible]	[illegible]	
36	12:48	1	"	4	[illegible]	
37	[illegible]	1	"	7	[illegible]	
						[illegible]
38	12:50	1	17.5	7	[illegible]	
39	[illegible]	1	"	[illegible]	[illegible]	
40	12:52	1	"	2.5	2.5	
41	12:53	1	"	[illegible]	2.5	
42	12:54	1	17	[illegible]	[illegible]	
43	12:57	[illegible]	"	0	0	[illegible]
44	[illegible]	1	"	[illegible]	[illegible]	
45	[illegible]	1	"	[illegible]	[illegible]	

[illegible]

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	1	17	[illegible]	4	
[illegible]	[illegible]	1	"	[illegible]	4	
[illegible]	1:03	[illegible]	"	[illegible]	[illegible]	
[illegible]	1:05	[illegible]	"	[illegible]	[illegible]	
51	[illegible]	1	"	[illegible]	[illegible]	
[illegible]	1:07	[illegible]	"	[illegible]	4	[illegible], 1:1[illegible]
55	1:15	0	"	[illegible]	0	
56	1:16	1	"	5	5	
57	1:17	1	"	4.5	4.5	
58	1:18	1	"	6	6	
59	1:19	1	"	6	[illegible]	
60	1:20	1	"	6	[illegible]	
61	1:21	1	"	3.5	3.5	
62	[illegible]	1	"	[illegible]	3	
63	1:23	1	"	[illegible]	3	
64	[illegible]	1	"	[illegible]	[illegible]	
65	1:25	1	"	5	[illegible]	Temp. changed, 1:25
66	1:26	0	19	0	[illegible]	New record sheet
67	1:27	1	"	[illegible]	1	[illegible], 1:30
68	1:30	[illegible]	"	0	0	
[illegible]	1:32	2	"	[illegible]	1	
70	1:33	1	"	2	[illegible]	
71	1:34	1	"	4.5	4.5	
72	1:35	1	"	7	[illegible]	
[illegible]	1:36	1	"	9	9	
74	1:37	1	"	7	7	
75	1:38	1	"	[illegible]	[illegible]	
76	[illegible]	1	"	6.5	6.5	
77	1:40	0	"	[illegible]	0	[illegible]
78	1:41	1	"	[illegible]	[illegible]	
79	1:42	1	"	[illegible]	4	Rest; began to move, 1:[illegible]
80	1:44	0	"	0	0	
81	[illegible]	1	"	[illegible]	6	
82	1:46	1	"	6	6	
[illegible]	1:47	1	"	[illegible]	[illegible]	
[illegible]	1:47:30	[illegible]	"	0	0	[illegible]
[illegible]	1:49	[illegible]	9.5	[illegible]	[illegible]	[illegible]
87	2:00	[illegible]	"	1	1	
88	2:09	[illegible]	"	3.5	0.4	[illegible]

No. of Observation	Time	Time Interval Min.	Temperature Degrees C	Total Distance Mm.	Rate Mm. per Min.	Remarks
89?	2:10	1	10.5	2.5	2.5	
90?	2:11	1	"	6	[illegible]	
91	[illegible]	1	"	4	[illegible]	
92?	2:13	1	"	7	7	
93	2:14	1	"	[illegible]	[illegible]	
94?	2:15	1	"	3.5	3.5	
95	2:16	1	"	[illegible]	[illegible]	
96	2:17	1	"	[illegible]	[illegible]	
97	2:18	1	"	2	2	
98	2:19	1	"	[illegible]	2	
99?	2:20	0	"	0	0	[illegible]
100	2:22:10	2.16	"	8	3.7	
101	2:23:10	1	"	[illegible]	3	


XXXVIII (a)
XXXVII
XXXVIII

PERFORMANCE RECORD
of
[illegible]

No. of Observation	Time	Time Elapsed Min.	Temperature Degrees F	Total Mileage Mi.	Rate Mi. per Min.	Remarks
0	1:03	0	21	0	0	
1	[illegible]	1	"	3	3	
[illegible]	1:05	1	"	[illegible]	2	
[illegible]	1:06	1	"	2	[illegible]	
[illegible]	[illegible]	1	"	2.5	2.5	
5	1:08	1	"	[illegible]	[illegible]	
6	1:09	1	"	3	3	
7	1:10	1	"	4.5	[illegible]	
[illegible]	1:11	1	"	3	3	
[illegible]	1:12	1	"	2	[illegible]	
10	1:13	1	"	2	2	
11	1:15	2	"	3	1.5	
12	1:16	1	"	[illegible]	[illegible]	
13	[illegible]	1	"	[illegible]	[illegible]	
[illegible]	1:18	1	"	[illegible]	[illegible]	
15	1:19	1	"	[illegible]	3	
						[illegible]
16	1:20	1	[illegible]	[illegible]	[illegible]	
17	1:21	1	"	3	[illegible]	
[illegible]	1:23	[illegible]	"	[illegible]	[illegible]	
[illegible]	1:29	[illegible]	"	[illegible]	0.33	
[illegible]	1:31	[illegible]	"	2	[illegible]	
[illegible]	1:33	[illegible]	"	[illegible]	1.5	

PERFORMANCE RECORD

of

[illegible]

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	0	[illegible]	[illegible]	0	
[illegible]	[illegible]	1	"	[illegible]	[illegible]	
[illegible]	2:48	1	"	8.5	8.5	
[illegible]	2:49	1	"	[illegible]	[illegible]	
[illegible]	2:50	1	"	5	5	
[illegible]	2:51	1	"	4.5	4.5	
[illegible]	2:52	[illegible]	"	[illegible]	5	
[illegible]	2:53	1	"	[illegible]	2	
[illegible]	2:54	1	"	10	10	
10	2:55	1	"	[illegible]	[illegible]	
[illegible]	2:56	1	"	4	[illegible]	
12	2:57	1	"	10	10	
[illegible]	2:58	1	"	[illegible]	8	
[illegible]	3:01	0	"	0	[illegible]	[illegible]
15	3:02	1	"	11	11	
16	3:03	1	"	13	13	
17	3:04	1	"	6	[illegible]	
18	3:05	1	"	[illegible]	[illegible]	
19	3:06	1	"	5	5	
[illegible]	3:08	0	"	0	0	New record sheet
21	3:09	1	"	6	6	
[illegible]	3:10	1	"	[illegible]	[illegible]	
23	3:11	[illegible]	9.5	[illegible]	[illegible]	[illegible] move, 3:14
[illegible]	3:16	2	"	[illegible]	5	
25	3:17	1	"	5	5	
27	3:19	[illegible]	"	5	2.5	
[illegible]	3:21	[illegible]	"	4	[illegible]	
[illegible]	3:23	2	"	[illegible]	1.5	
30	3:25	2	"	[illegible]	1.5	
31	[illegible]	2	"	5	2.5	
32	3:29	2	"	6	3	
33	3:31	[illegible]	"	6	[illegible]	
34	3:33	2	"	7	3.5	
35	3:35	[illegible]	"	[illegible]	[illegible]	
37	[illegible]	0	"	0	0	[illegible]
38	3:40	[illegible]	"	[illegible]	[illegible]	
39	3:42	2	"	4.5	2.25	
40	3:44	[illegible]	"	[illegible]	[illegible]	
41	3:46	[illegible]	"	3	1.5	
42	3:48	[illegible]	"	3	1.5	
43	3:50	[illegible]	"	3	1.5	[illegible]
44	3:51	[illegible]	11	[illegible]	[illegible]	[illegible]

[illegible]

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	3:52	[illegible]	16	[illegible]	[illegible]	[illegible]
[illegible]	4:00	[illegible]	20	[illegible]	0	
47	4:02	[illegible]	"	12	[illegible]	
[illegible]	4:04	2	16	[illegible]	3.5	[illegible]
[illegible]	4:06	2	"	7	3.5	
50	4:08	2	"	7	3.5	
[illegible]	4:10	2	"	[illegible]	[illegible]	
52	4:12	2	"	[illegible]	[illegible]	[illegible] 4:15
54	4:15	0	"	0	0	[illegible]
55	4:17	[illegible]	"	[illegible]	1.5	
56	4:19	2	"	3	1.5	
57	4:21	[illegible]	"	[illegible]	1.25	
58	[illegible]	2	"	3	1.5	
[illegible]	[illegible]	0	"	[illegible]	0	[illegible]
						Temp. changed, 4:25:30
60	4:25:30	[illegible]	9.5	4	[illegible]	
61	4:32	4	"	4	1	[illegible] 4:45
[illegible]	4:45	0	14	0	0	[illegible]
63	4:48	[illegible]	"	3	1	
64	4:50	2	"	[illegible]	3.5	
65	4:52	2	"	[illegible]	[illegible]	Temp. changed, 4:52:30
66	4:54	2	17.5	4	[illegible]	
[illegible]	4:56	2	"	7	3.5	
68	4:58	2	"	3	1.5	
69	5:00	[illegible]	"	2	1	

*Graph on same Plate with Individual [illegible]VII.

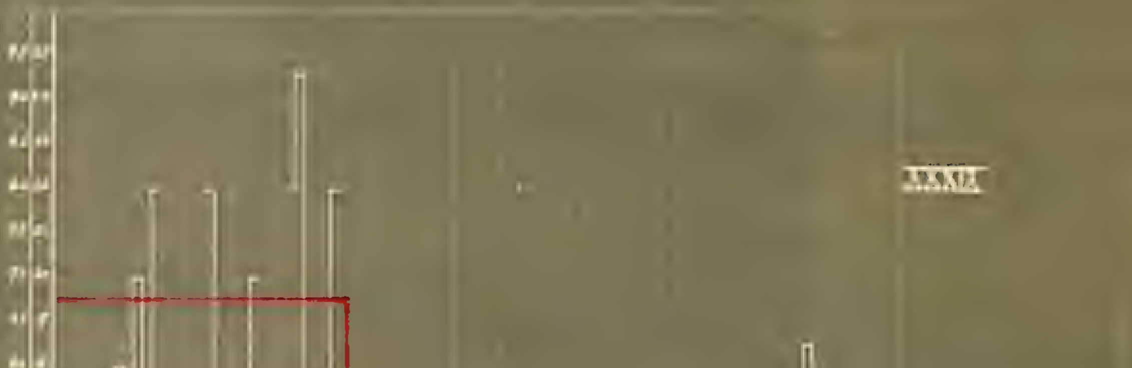
Individual [illegible] *

[illegible]	4:00	0	20	0	[illegible]
[illegible]	4:02	[illegible]	"	11	5.5
[illegible]	4:04	[illegible]	[illegible]	[illegible]	1.5
49	4:06	[illegible]	"	4	[illegible]
50	4:08	[illegible]	"	[illegible]	1
51	4:10	[illegible]	"	[illegible]	1
[illegible]	4:12	[illegible]	"	[illegible]	[illegible]
[illegible]	4:13	[illegible]	"	[illegible]	[illegible]

[illegible] - (3)

No. of Observation	Time	Time Interval Min.	Temperature Degrees C	Total Distance Cm.	Speed Cm. per Min.	Remarks
54	[illegible]	[illegible]	[illegible]	[illegible]	3	
55	4:17	[illegible]	"	[illegible]	7	
[illegible]	[illegible]	[illegible]	"	[illegible]	2.5	
57	[illegible]	[illegible]	"	[illegible]	4.5	
[illegible]	[illegible]	[illegible]	"	[illegible]	4.5	

*Graph on same Plate with Individual [illegible]VII.



PERFORMANCE RECORD

of

INDIVIDUAL XXXIX

No. of Observation	Time	Time Interval Min.	Temperature Degrees C	Total Distance Mm.	Rate Mm. per Min.	Remarks
1	2:39	0	19.5	0	0	
2	2:40	1	"	4	4	
3	2:41	1	"	4.5	4.5	
4	2:42:10	1.16	"	4	3.45	
5	2:43:10	1	"	6	6	
6	2:44	.8	"	4	5	
7	2:45	1	"	7	7	
8	2:46	1	"	5	5	
9	2:47	1	"	8	8	
10	2:48	0	"	0	0	New record sheet
11	2:49	1	"	5	5	
12	2:50	1	"	3	3	
12a	2:51	1	"	3	3	
13	2:52	0	"	0	0	New starting point
14	2:53	1	"	8	8	
15	2:55	2	"	9	4.5	
16	2:56	1	"	5	5	
17	2:57	1	"	3	3	
18	2:58	1	"	4	4	
19	3:00	2	"	14	7	
20	3:01	0	"	0	0	
21	3:02	1	"	8	8	
22	3:03	1	"	10	10	
23	3:06	3	"	12	4	
24	3:07	1	"	8	8	
						3:08 - 3:19, pspd. active but no locomotion
						Temp. changed, 3:16
30	3:19	0	11	0	0	New record sheet
31	3:25	6	"	5	0.83	
32	3:26	1	12	5.5	5.5	
33	3:28	2	"	4	2	Rest, 3:28 - 3:37
35	3:37	0	"	0	0	New record sheet
36	3:39	2	13	6	3	Temp. changed, 3:37
37	3:41	2	"	4	2	
38	3:43	2	14	3	1.5	Temp. changed, 3:41
39	3:45	2	"	6	3	Rest; began to move,
40	3:49	2	"	4	2	3:47
41	3:51	2	"	6	3	

XXXIX - (2)

No. of Observation	Time	Time Interval Min.	Temperature Degrees C	Total Distance Mm.	Rate Mm. per Min.	Remarks
42	3:53	2	15	9	4.5	
43	3:54	0	"	0	0	New record sheet
44	3:56	2	"	7	3.5	
45	3:58	2	"	11	5.5	
46	3:59	1	"	5	5	
47	4:00	1	"	6	6	
50	4:01	1	"	4	4	
51	4:04	3	"	9	3	
52	4:06	2	"	7	3.5	
53	4:07	0	"	0	0	New record sheet
54	4:11	4	"	10	2.5	
55	4:15	4	"	5	1.25	
56	4:21	6	12	6	1	
57	4:23	2	"	9	4.5	
58	4:25	2	"	8	4	

FOLD OUT

PERFORMANCE RECORD
of
INDIVIDUAL XL

No. of Observation	Time	Time Interval Min.	Temperature Degrees C	Total Distance Mm.	Rate Mm. per Min.	Remarks
1	9:13	0	21	0	0	
2	9:14	1	"	5	5	
3	9:15	1	"	10	10	
4	9:17	2	"	8	4	
5	9:19	2	"	8	4	
6	9:20	1	"	8	8	
7	9:21	1	"	6	6	
8	9:22	1	"	6	6	
9	9:23	1	"	7	7	
10	9:24	0	"	0	0	New record sheet
11	9:25	1	"	8.5	8.5	
12	9:26	1	"	7	7	
13	9:27	1	"	5	5	
14	9:28	1	"	7	7	
15	9:29	1	"	5	5	Animal floating
17	9:32	0	"	0	0	New record sheet
18	9:34	2	"	6	3	
19	9:35	0	20	0	0	New record sheet
20	9:36	1	"	3	3	
21	9:37	1	"	5	5	
22	9:38	1	"	9	9	
23	9:39	1	"	8	8	
24	9:40	1	"	8	8	
25	9:41	1	"	7	7	
26	9:42	1	"	7	7	
27	9:43	1	"	6	6	
28	9:44	1	"	5	5	
29	9:45	1	"	6	6	
30	9:46	0	"	0	0	New record sheet
31	9:47	1	"	8	8	
32	9:48	1	"	10	10	
33	9:49	1	"	8	8	
34	9:51	2	"	9	4.5	
35	9:52	1	"	3	3	
36	9:53	1	"	2	2	Animal floating
37	9:54	1	"	2	2	
38	9:55	0	"	0	0	New starting point
39	9:56	1	"	6	6	
40	9:57	1	"	7	7	
41	9:57:30	0	"	0	0	New record sheet
42	9:58:30	1	"	7	7	
43	9:59:30	1	"	8.5	8.5	
44	10:00:30	1	12.5	9	9	Temp. changed, 10:00:3
45	10:01:30	1	"	2	2	
46	10:03:30	2	"	2	1	
47	10:05:30	2	"	3	1.5	
48	10:07:30	2	"	3	1.5	

XL - (2)

No. of Observation	Time	Time Interval Min.	Temperature Degrees C	Total Distance Mm.	Rate Mm. per Min.	Remarks
49	10:12	0	12.5	0	0	New starting point
50	10:14	2	"	8	4	
51	10:16	2	"	8	4	
52	10:18	2	"	12	6	
53	10:20	2	"	8	4	
54	10:22	2	"	10	5	
55	10:24	2	"	12	6	
56	10:26	2	"	12	6	
57	10:27	0	"	0	0	New record sheet
52S	10:29	2	"	11	5.5	Nos. 52-57 were repeated by mistake; on record sheet indicated by "S"
53S	10:31	2	"	10	5	
54S	10:32	1	"	6	6	
55S	10:33	1	"	4	4	
56S	10:35	2	9	5	2.5	Temp. changed, 1:35
57S	10:37	0	"	0	0	New record sheet
58	10:40	3	"	2.5	.8	
59	10:45	0	"	0	0	Rest; began to move, 10:45
60	10:47	2	"	3	1.5	Rest; began to move, 10:50
61	10:53	3	9.5	3	1	Temp. raised slightly, 10:53
62	10:54:20	0	"	0	0	Rest; began to move, 10:56
63	10:58	2	"	4	2	Rest; began to move, 11:09:15 Pspd. active
64	11:09:15	0	10.5	0	0	New record sheet
65	11:11	1.75	"	3	1.7	
66	11:13	2	"	7.5	3.7	
67	11:15	2	"	7.5	3.7	
68	11:17	2	"	4	2	
69	11:19	2	"	5	2.5	
70	11:20	0	"	0	0	New record sheet
71	11:22	2	"	6	3	
72	11:25	3	"	10	3.3	Temp. changed, 11:25:30
73	11:26	1	Variable	4	4	
74	11:28	2	16.5	8	4	
75	11:30	2	"	8	4	
76	11:32	2	15	13	6.5	

XL - (3)

No. of Observation	Time	Time Interval Min.	Temperature Degrees C	Total Distance Mm.	Rate Mm. per Min.	Remarks
77	11:34	2	15	8	4	
78	11:35	0	"	0	0	New record sheet
79	11:37	2	"	6	3	
80	11:39	2	"	4	2	
81	11:41	2	"	2	1	
82	11:44	3	"	7	2.33	
83	11:46	2	"	4	2	
84	11:48	2	"	7	3.5	
85	11:50	2	"	4	2	
86	11:52	2	"	4	2	

FOLD OUT

[illegible]

of

[illegible]

No. of Observation	Time	Time Interval Min.	Temperature Degrees C	Total Distance Mm.	Rate Mm. per Min.	Remarks
1	10:47	0	[illegible]	0	0	
2	10:48	1	"	12	12	
3	10:49	1	"	14	14	
4	10:50	1	"	14	14	
5	10:51	1	"	11	11	
6	10:51:30	[illegible]	"	0	0	[illegible]
7	10:53	1.5	"	19	12.7	
8	10:54	1	"	6	6	
9	10:55	1	"	12	12	
10	10:56	1	"	6	6	
11	10:57	1	"	4	6	
12	10:58	1	"	12	12	
13	10:58:30	[illegible]	"	[illegible]	0	[illegible]
14	11:00	1.5	"	15	10	
15	11:01	1	"	11	11	
16	11:02	1	"	12	12	
17	11:03	1	"	11	11	
18	11:04	1	"	6	6	
19	11:05	[illegible]	"	[illegible]	0	[illegible]
20	11:06	[illegible]	"	[illegible]	[illegible]	[illegible] direction
21	11:07	1	"	2.5	2.5	
22	11:08	1	"	[illegible]	2	
23	11:13	5	"	[illegible]	1.2	
24	11:14	1	21.5	12	12	
25	11:15	1	"	15	15	
26	11:16	1	"	14	14	
27	11:18	[illegible]	"	0	0	[illegible]
28	11:19	1	"	14	14	
29	11:20	1	"	10	10	
30	11:22	2	"	21	10.5	
31	11:23	1	"	14	14	
32	11:24:30	0	10.5	0	0	Temp. changed, 11:24 [illegible] 11:[illegible]
33	11:33	[illegible]	"	7	1	
34	11:38	5	10	[illegible]	1.3	[illegible] 11:38
35	11:39	[illegible]	"	[illegible]	1	

[illegible]

[illegible] 11:42 - 11:52

[illegible]

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Remarks
39	11:52	0	11	-	-	
40	[illegible]	[illegible]	"	[illegible]	1	
41	12:00:30	0	"	[illegible]	[illegible]	[illegible]
42	12:04	3.5	"	[illegible]	1.1	
						[illegible]
43	12:08:30	0	13	[illegible]	0	[illegible]
44	12:11	2.5	"	3	1.2	
45	12:13	2	"	5	2.5	
[illegible]	[illegible]	[illegible]	"	[illegible]	[illegible]	
47	12:17	[illegible]	"	[illegible]	4	
[illegible]	12:19	[illegible]	"	10.5	5.2	
49	12:21	[illegible]	"	8.5	4.2	
50	[illegible]	2	"	6.5	3.2	
51	12:25	2	"	9	4.5	
52	12:26	0	"	0	0	[illegible]
[illegible]	12:28	2	"	10	5	
54	12:30	2	"	7	3.5	
55	12:32	2	"	11	6.5	
56	[illegible]	2	"	10	5	
57	12:36	2	"	8	4	
58	12:37	0	"	0	0	[illegible]
59	12:39	[illegible]	"	10	5	
60	[illegible]	2	"	11	5.5	
61	12:43	2	"	10	5	
62	12:45	2	"	9	4.5	
63	12:47	2	"	6	3	
64	12:49	[illegible]	"	[illegible]	[illegible]	
65	12:50	1	"	4.5	4.5	
66	12:51	0	"	0	0	New record sheet
67	12:53	[illegible]	"	9	4.5	Temp. changed, 12:54
68	12:55	2	"	7	3.5	
69	12:57	[illegible]	14	5	2.5	
70	12:59	2	"	10	5	
71	1:01	2	15	12	[illegible]	
72	1:03	[illegible]	"	[illegible]	4	
73	1:05	[illegible]	"	6	3	
74	1:07	2	"	5	2.5	
						[illegible]
77	1:14	[illegible]	"	1.5	.75	
78	1:16	2	"	2.5	1.25	[illegible] 1:23
80	1:25	[illegible]	"	7	3.5	
81	1:27	[illegible]	"	4	[illegible]	
[illegible]	1:29	[illegible]	"	[illegible]	[illegible]	
83	1:31	2	"	[illegible]	[illegible]	

[illegible] - ([illegible])

No. of observation	Time	Time interval min.	Temperature degrees C	Total distance cm.	Rate cm. per min.	Remarks
[illegible]	[illegible]	[illegible]	1[illegible]	[illegible]	[illegible]	
85	1:35	[illegible]	"	[illegible]	3.5	
[illegible]	[illegible]	[illegible]	"	7	3.5	
87	1:39	[illegible]	20.5	5	2.5	[illegible]
88	1:41	[illegible]	"	1	.5	
89	1:43	0	"	0	[illegible]	[illegible]
90	1:45	[illegible]	"	[illegible]	1.5	
						[illegible] 1:50
91	1:50	0	"	0	0	[illegible]
92	1:52	[illegible]	"	[illegible]	1	
93	1:54	[illegible]	"	5	2.5	
94	1:56	2	"	13	6.5	
95	1:58	2	"	13	6.5	
96	[illegible]	2	"	3	1.5	
97	[illegible]	0	"	0	[illegible]	[illegible]
98	2:06	[illegible]	"	5	2.5	Temp. changed, 2:07:30
99	2:08	2	"	5	2.5	
100	2:10	2	Variable	[illegible]	[illegible]	Temp. variable
101	[illegible]	[illegible]	25	[illegible]	[illegible]	
102	[illegible]	2	29	6	3	
103	2:16	[illegible]	"	0	0	[illegible]
						[illegible]
105	2:27	[illegible]	27	[illegible]	[illegible]	[illegible]
106	2:32	[illegible]	"	7	2.3	
107	[illegible]	[illegible]	"	7	3.5	
108	2:36	[illegible]	"	10	[illegible]	
109	[illegible]	[illegible]	"	13	6.5	Rests; begins to move, [illegible]
110	2:42	[illegible]	"	7	3.5	
111	[illegible]	[illegible]	"	[illegible]	3.5	
[illegible]	2:47	3	"	[illegible]	4.3	
113	[illegible]	[illegible]	"	[illegible]	2.5	
114	2:50:30	0	"	[illegible]	[illegible]	New record sheet
115	2:53	2.5	"	7	[illegible]	
[illegible]	2:56	3	[illegible].5	[illegible]	2.7	

XLI – [illegible]

No. of Observation	Time	Time Interval Min.	Temperature Degrees	Total distance mm.	Rate mm. per min.	Remarks
117	[illegible]	0	[illegible]	[illegible]	[illegible]	[illegible]
118	3:01	2.5	19.5	[illegible]	[illegible]	
119	[illegible]	[illegible]	"	[illegible]	1	
120	3:05	[illegible]	"	[illegible]	1.5	
121	3:07	2	"	[illegible]	1	
[illegible]	3:09	[illegible]	"	3	[illegible]	


XLII


XLIV

PERFORMANCE RECORD

of

[illegible]

No. of Observation	Time	Time Interval Min.	Temperature Degrees C	Total Distance Cm.	Rate Cm. per Min.	Remarks
1	[illegible]	0	20	0	-	
[illegible]	[illegible]	1	"	[illegible]	[illegible]	
3	1:50	1	"	[illegible]	[illegible]	
[illegible]	1:51	1	"	[illegible]	[illegible]	[illegible]
5	1:52	1	16.5	[illegible]	[illegible]	
[illegible]	1:53	1	"	[illegible]	[illegible]	
7	1:54	0	16	0	0	[illegible] 1:55
[illegible]	1:56	1	"	[illegible]	[illegible]	
9	1:57	1	"	5	5	
10	1:58	1	"	9	9	
11	1:59	1	"	5	5	
12	2:00	1	"	5	[illegible]	
13	2:01	1	"	5	5	
14	[illegible]	1	"	5	5	
15	2:03	0	"	0	0	[illegible]
16	2:04	1	"	5	5	
17	2:05	1	"	3.5	3.5	
18	2:06	1	"	[illegible]	[illegible]	
19	2:07	1	"	2.5	2.5	
20	2:08	1	"	4.5	4.5	
21	[illegible]	1	"	3.5	3.5	
[illegible]	2:10	[illegible]	"	[illegible]	[illegible]	
23	2:11	1	"	[illegible]	4	
[illegible]	2:12	1	"	6	6	
[illegible]	2:13	1	"	4	[illegible]	
26	2:14	1	"	4	[illegible]	
27	2:15	1	"	4	4	
28	2:16	1	"	[illegible]	[illegible]	
29	2:17	1	"	[illegible]	4	
30	2:18	1	"	7	7	
31	2:19	1	"	[illegible]	7	

[illegible]

FOLD OUT

[illegible]

of

[illegible]

No. of [illegible]	[illegible]	[illegible]	[illegible] Degrees C	Total [illegible]	[illegible]	[illegible]
1	11:2[illegible]	1	20	0	[illegible]	
[illegible]	11:21	[illegible]	"	3.5	2.5	
[illegible]	11:25	[illegible]	"	4.5	4.5	
[illegible]	11:26	[illegible]	"	[illegible]	[illegible]	
5	11:27	[illegible]	"	[illegible]	[illegible]	
6	11:28	1	"	[illegible]	[illegible]	
7	11:29	1	"	4	[illegible]	
[illegible]	11:30	1	"	[illegible]	[illegible]	
[illegible]	11:31	1	"	2	[illegible]	
10	11:32	1	"	2	[illegible]	
11	11:34	2	"	[illegible]	1	
[illegible]	11:36	2	"	5	2.5	
13	11:38	2	"	2.5	1.25	
14	11:40	[illegible]	"	[illegible]	[illegible]	[illegible] 11:44
15	11:46	0	"	0	0	[illegible]
16	11:48	2	"	3.5	1.75	
17	11:50	[illegible]	"	[illegible]	1.5	
18	11:52	0	"	0	0	New record sheet
19	11:54	2	"	20	10	
[illegible]	[illegible]	[illegible]	"	12	6	[illegible]
22	1:01:30	[illegible]	10.5	[illegible]	0	[illegible]
23	1:03	[illegible]	"	2.5	1.7	
[illegible]	1:05	[illegible]	"	4.5	2.25	
[illegible]	1:08	[illegible]	"	12	[illegible]	
26	1:10	[illegible]	[illegible]	[illegible]	[illegible]	
[illegible]	1:12	2	"	5	2.5	
[illegible]	1:15	3	"	[illegible]	1	[illegible] 1:17
[illegible]	1:23	[illegible]	"	[illegible]	0.7	
30	1:26	[illegible]	"	3.5	[illegible]	[illegible]
31	1:34	[illegible]	12	[illegible]	0.7	
32	1:3[illegible]	[illegible]	[illegible]	4	1	
33	1:41	[illegible]	[illegible]	3	1	
34	1:44	3	[illegible]	1	0.[illegible]	
35	1:52	[illegible]	"	[illegible]	[illegible]	[illegible] 1:52
[illegible]	1:55	3	13	[illegible]	0.7	[illegible]
37	1:57	[illegible]	"	[illegible]	[illegible]	[illegible]
[illegible]	1:5[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	2:01	[illegible]	"	[illegible]	[illegible]	
40	[illegible]	[illegible]	"	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible]	"	[illegible]	[illegible]	

[illegible] - [illegible]

No. of Observation	Time	Trail Interval Min.	Temperature Degrees C	Total Distance Mm.	Rate mm. per Min.	Remarks
45	[illegible]	[illegible]	15.5	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible]	"	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible]	"	10	[illegible]	
[illegible]	[illegible]	[illegible]	"	13	[illegible]	
[illegible]	2:18:30	[illegible]	"	[illegible]	0	[illegible]
51	[illegible]	1.5	"	[illegible]	[illegible]	
[illegible]	2:21	[illegible]	"	[illegible]	[illegible]	
[illegible]	[illegible]	1	"	4	[illegible]	
[illegible]	2:24	[illegible]	"	6	[illegible]	
[illegible]	[illegible]	2	"	[illegible]	[illegible]	
56	2:28	[illegible]	"	5	2.5	
57	[illegible]	[illegible]	"	[illegible]	[illegible]	
58	[illegible]	[illegible]	"	11	5.5	
[illegible]	[illegible]	[illegible]	"	7	3.5	
60	[illegible]	2	"	9	4.5	
61	2:36:30	0	"	0	0	[illegible]
[illegible]	[illegible]	1.5	[illegible]	[illegible]	2.7	[illegible]
[illegible]	[illegible]	2	"	[illegible]	1	
64	2:42	[illegible]	"	[illegible]	[illegible]	
65	2:44	2	"	3	1.5	
[illegible]	[illegible]	0	"	0	0	[illegible] 2:55
68	2:57	[illegible]	"	[illegible]	[illegible]	
[illegible]	[illegible]	2	"	1.5	0.75	
[illegible]	3:02	3	"	[illegible]	0.7	
71	3:05	3	"	4	1.3	
72	3:07	[illegible]	"	1	0.5	
[illegible]	3:11	[illegible]	"	7	1.7	
74	3:15	[illegible]	"	10	2.5	
75	[illegible]	3	"	[illegible]	[illegible]	[illegible]
76	3:[illegible]	[illegible]	13.5	[illegible]	1.5	
77	[illegible]	[illegible]	12.5	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	"	[illegible]	1	[illegible]
[illegible]	3:51	[illegible]	10.5	[illegible]	[illegible]	[illegible]
[illegible]	3:[illegible]	4	"	3	[illegible]	
[illegible]	[illegible]	[illegible]	"	[illegible]	[illegible]	

[illegible]

of

[illegible] XLIV *

[illegible]	[illegible]	Time [illegible] Min.	[illegible]	[illegible]	[illegible]	[illegible]
1	10:27	0	18	[illegible]	0	
[illegible]	10:28	1	"	[illegible]	[illegible]	
[illegible]	10:29	1	"	7	7	
[illegible]	10:31	[illegible]	"	15	7.5	
5	10:33	[illegible]	"	[illegible]	4.5	
[illegible]	10:35	[illegible]	"	7	3.5	
7	10:37	[illegible]	"	[illegible]	3.5	
[illegible]	10:39	[illegible]	"	[illegible]	1.5	
9	10:41	[illegible]	"	[illegible]	[illegible]	
10	10:43	0	"	0	0	[illegible]
11	10:45	[illegible]	"	13	6.5	
[illegible]	10:47	2	"	13	6.5	
13	10:49	2	"	[illegible]	1	
14	10:53:30	0	"	-	-	[illegible]
15	10:56	0	"	-	-	" "
16	10:58	[illegible]	16	9	4.5	Temp. changed, 10:57
17	11:00	2	"	5	2.5	
18	11:02	[illegible]	"	15	7.5	
19	11:04	2	"	[illegible]	6	
20	11:06	[illegible]	"	[illegible]	5	
21	11:08	[illegible]	"	[illegible]	[illegible]	
22	11:09	0	"	0	0	[illegible]
23	11:11	2	"	3.5	1.75	
						[illegible]
25	11:22	0	"	[illegible]	0	New starting point
[illegible]	11:24	2	"	[illegible]	1	
27	11:27	0	16.2	[illegible]	0	[illegible]
28	11:29	2	"	[illegible]	1	[illegible] 11:33
30	11:33	0	16	0	0	[illegible]
31	11:34	1	"	2	2	
32	11:35	1	"	[illegible]	[illegible]	
33	11:37	[illegible]	17	10	[illegible]	[illegible]
36	11:40	2	13.8	2	1	[illegible]
37	11:41	0	"	0	0	[illegible]
38	11:47	1	"	2.5	2.5	
[illegible]	11:53	[illegible]	"	3.5	0.9	

*Graph on same Plate with individual XLII.

FOLD OUT

PERFORMANCE RECORD
of
INDIVIDUAL XLV

No. of Observation	Time	Time Interval Min.	Temperature Degrees C	Total Distance Mm.	Rate Mm. per Min.	Remarks
1	12:59:30	0	17	0	0	
2	1:01	1.5	"	8	5.3	
3	1:03	2	"	10	5	
4	1:05	2	"	12	6	
5	1:07	0	"	0	0	New record sheet
6	1:09	2	"	4	2	
7	1:11	2	"	4	2	
8	1:13	2	"	11	5.5	
9	1:15	2	"	10	5	
10	1:17	2	"	11	5.5	
11	1:20	3	12.5	12	4	Temp. changed, 1:18
12	1:21	0	"	0	0	New record sheet
13	1:23	2	"	2.5	1.25	
14	1:25	2	"	3.5	1.75	
15	1:27	2	"	4	2	
16	1:29	2	"	3	1.5	
17	1:31	2	"	9	4.5	
18	1:33	2	"	6	3	
19	1:35	2	"	3	1.5	
20	1:37	2	"	4	2	
21	1:39	2	"	3	1.5	Temp. changed, 1:41
22	1:43	0	14	0	0	New record sheet
23	1:45	2	"	4	2	
24	1:47	2	"	5	2.5	
25	1:49	2	"	2	1	
26	1:51	2	"	5	2.5	
27	1:53	2	"	3	1.5	Temp. changed, 1:54
28	1:55	0	15	0	0	
29	1:59	0	"	0	0	New record sheet
30	2:01	2	"	12	6	
31	2:03	2	"	8	4	
						Rest; began to move, 2:24
32	2:24	0	13.8	0	0	Temp. changed, 2:20
33	2:26	2	"	5	2.5	
34	2:28	2	"	6	3	
35	2:30	2	"	4	2	Temp. changed, 2:31
36	2:32	2	12.2	3	1.5	
37	2:34	2	"	2.5	1.25	
38	2:36:30	2.5	"	4	1.6	
39	2:39	2.5	"	4	1.6	
40	2:42	3	"	4	1.3	
41	2:45	3	"	7	2.33	
42	2:47	2	"	2	1	
43	2:50	3	"	4	1.33	

XLV - (2)

No. of Observation	Time	Time Interval Min.	Temperature Degrees C	Total Distance Mm.	Rate Mm. per Min.	Remarks
44	2:52	0	12.2	0	0	New record sheet
45	2:54	2	"	2	1	Temp. changed, 2:54
46	2:56	0	11	0	0	
47	2:58	2	"	2	1	
48	3:01	3	"	2	0.7	
49	3:03	2	"	2	1	
50	3:06	3	"	1	0.3	
51	3:12	6	"	2	0.3	
52	3:18	6	"	1	0.16	
53	3:23	5	"	2	0.4	
54	3:26	3	"	1	0.3	
						Temp. changed, 3:27
55	3:29	3	13	2	0.66	
56	3:31	0	"	0	0	New record sheet
57	3:33	2	"	2	1	
58	3:38	5	"	1.5	0.3	
59	3:43	5	"	2	0.4	
60	3:46:30	3.5	"	2	0.6	
61	3:54	8	"	2	0.25	
62	3:59	5	"	3	0.6	

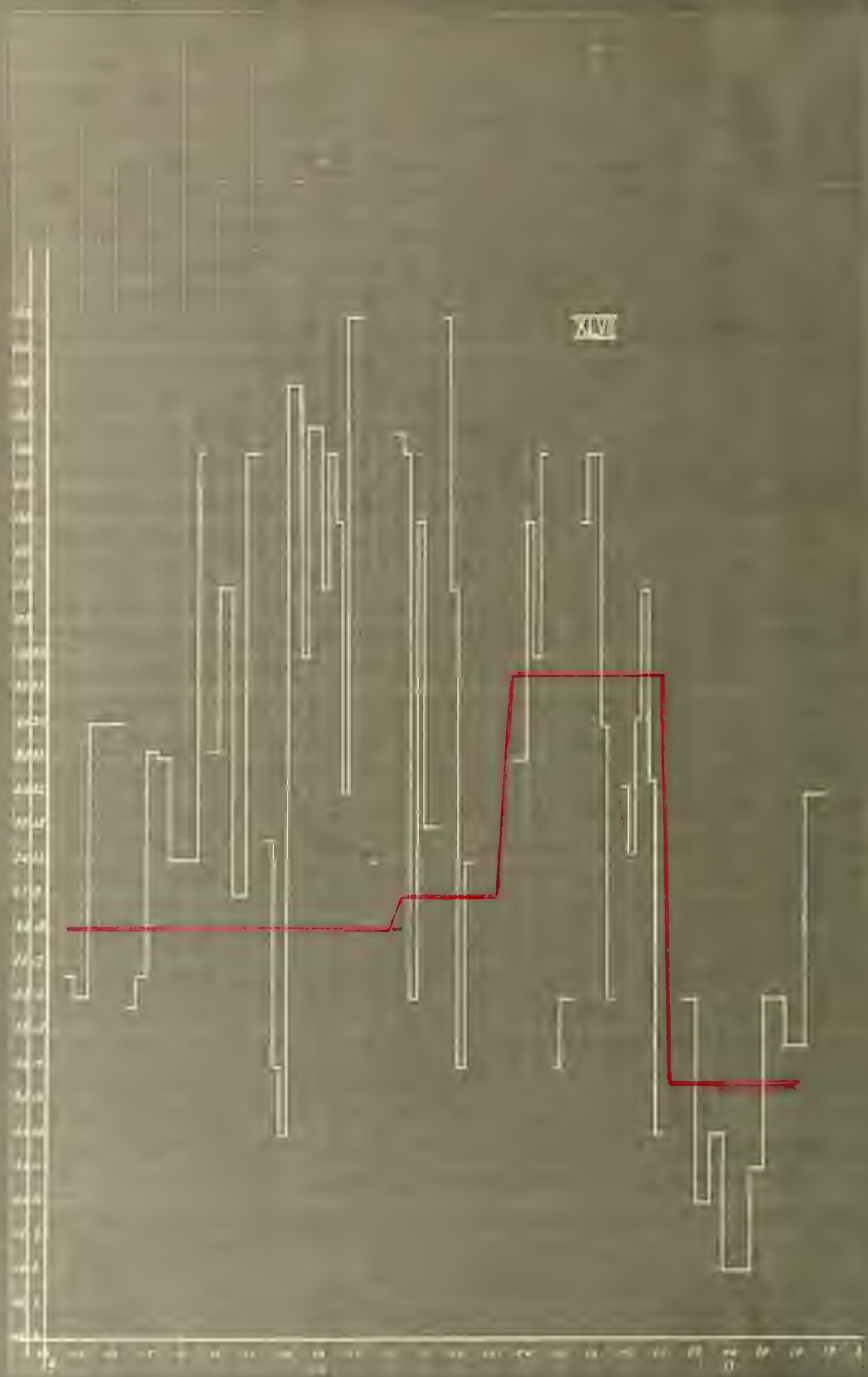
FOLD OUT

[illegible] RECORD
of
[illegible]

[illegible] Observation	Time	[illegible] Min.	Temperature Degrees C	Total [illegible]	[illegible] per [illegible]	Remarks
1	1:06	0	14	0	0	
[illegible]	1:08	2	"	9	4.5	
3	1:10	2	"	6.5	3.25	
[illegible]	1:12:15	2.25	"	7	3.1	
5	1:14	1.75	"	7	3.4	
[illegible]	1:16	[illegible]	"	[illegible]	4.5	
[illegible]	1:18	2	"	[illegible]	3	
8	1:20	2	"	11	5.5	
[illegible]	1:22	2	"	19	9.5	
10	1:23	0	"	0	[illegible]	New record sheet
11	1:25	[illegible]	"	10	5	[illegible]
12	1:27	[illegible]	14.5	10	5	
13	1:29	2	"	16	8	
14	1:31	2	"	15	7.5	
15	1:33	[illegible]	"	7	3.5	
16	1:35	[illegible]	"	[illegible]	3.5	
17	1:[illegible]	0	"	0	0	New record sheet
18	1:38	2	"	12	6	[illegible]
19	1:40	2	10	9	4.5	
20	1:42	2	"	5	2.5	
21	1:46:30	0	"	[illegible]	0	[illegible] locomotion
22	1:49:30	0	12	0	0	
23	1:53	3.5	"	5	1.4	
24	1:55	2	"	3	1.5	
25	1:57	0	"	[illegible]	0	[illegible]
26	1:59	[illegible]	"	4.5	2.25	
27	2:01	[illegible]	"	3.5	1.75	
28	2:03	0	"	-	-	[illegible]
29	2:07	0	"	-	-	" "
30	2:09	0	"	-	-	" "
31	2:11	0	"	-	-	" "
[illegible]	2:13	[illegible]	[illegible]	5	2.5	[illegible]
33	2:16	3	"	6	2	
34	2:19	3	"	1.5	0.5	
35	2:22	3	"	3	1	
36	2:25	3	"	[illegible]	1.3	
37	2:26	0	"	0	0	New record sheet
38	[illegible]	[illegible]	"	7	2.3	
39	2:32	3	"	[illegible]	2.3	[illegible]
40	2:35	[illegible]	[illegible]	10	3.3	

[illegible] (E)

No. of [illegible]	[illegible]	[illegible] Min.	[illegible] C	Total [illegible] Cm.	[illegible] Cm. per Min.	[illegible]
[illegible]	2:39	4	1[illegible]	[illegible]	[illegible]	
[illegible]	2:42	[illegible]	"	11	3.7	
[illegible]	[illegible]	0	"	-	-	[illegible]
44	2:47	[illegible]	"	8	4	
45	[illegible]	2	"	8	[illegible]	
46	[illegible]	2	"	8	[illegible]	
47	2:54	3	"	[illegible]	2.7	
[illegible]	2:57:30	[illegible]	"	0	0	New record sheet
[illegible]	3:02	4.5	18	14	3.1	[illegible]
[illegible]	3:05	[illegible]	"	8	2.7	
51	3:07	2	"	3	1.5	
52	3:11	[illegible]	"	34	8.5	
53	3:13	[illegible]	"	12	[illegible]	
54	3:14	0	"	[illegible]	0	New record sheet
55	3:16	2	"	11	5.5	
56	3:18	2	"	6.5	3.25	
57	3:20	2	"	5	2.5	
[illegible]	3:23	3	"	14	4.7	
[illegible]	3:25	2	"	3	1.5	
60	3:27	2	"	[illegible]	[illegible]	
						[illegible]
[illegible]	3:30	0	16	0	0	New record sheet
62	3:33	[illegible]	"	13	4.3	
63	3:36	[illegible]	"	[illegible]	4.3	
64	3:39	3	"	[illegible]	7.7	
65	3:42	[illegible]	"	[illegible]	4.3	
66	3:42:30	0	"	0	0	New record sheet
67	3:46	3.5	"	3	0.85	
68	3:46:30	0	"	0	0	New starting point
69	3:49	2.5	"	4	1.6	
70	3:51	[illegible]	"	11	5.5	
71	3:53	[illegible]	"	7	3.5	[illegible] 3:58
74	4:00	[illegible]	"	11	5.5	
75	4:02	[illegible]	"	13	6.5	
76	4:04	[illegible]	"	7	3.5	


XLVI

PERFORMANCE RECORD

of

[illegible]

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]	1.5	"	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible]	"	10	5	
[illegible]	9:28	[illegible]	"	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible]	"	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible]	"	13	[illegible]	
7	9:31:30	0	"	[illegible]	0	[illegible]
[illegible]	[illegible]	[illegible]	"	7	4.66	
[illegible]	[illegible]	1.5	"	[illegible]	5.33	
10	[illegible]	1.5	"	13	8.66	
11	9:38	[illegible]	"	17	8.5	
[illegible]	9:40	[illegible]	"	14	7	
13	9:42	[illegible]	"	14	7	
[illegible]	[illegible]	1	"	13	13	
[illegible]	[illegible]	0	"	0	[illegible]	New record sheet
[illegible]	9:45	1.5	"	13	8.66	
17	[illegible]	[illegible]	"	[illegible]	11	
18	9:49	2	"	13	6.5	
19	9:51	[illegible]	"	26	13	
[illegible]	9:51:30	[illegible]	"	0	[illegible]	New record sheet
21	9:53	1.5	"	11	7.33	
[illegible]	[illegible]	1	"	[illegible]	4	
[illegible]	9:55	1	"	3	3	
[illegible]	9:56	1	"	14	14	
[illegible]	9:57	1	"	14	14	
[illegible]	9:58	1	"	10	10	
27	9:58:35	0	"	[illegible]	0	New record sheet
[illegible]	10:00	1.4	"	19	13.6	
[illegible]	10:01	1	"	11	11	
[illegible]	10:02	[illegible]	"	13	13	
31	10:03	[illegible]	"	12	12	
[illegible]	10:04	1	"	8	8	
[illegible]	10:05	1	"	15	15	
[illegible]	10:06	1	"	15	15	
35	10:07	[illegible]	"	[illegible]	0	[illegible]
36	10:08	1	"	7	[illegible]	
37	10:09	0	"	0	0	[illegible]
38	10:10:30	0	"	0	0	[illegible] 10:10:30
39	[illegible]	1.5	19	20	13.3	
40	10:13	1	"	13	13	
41	[illegible]	1	"	5	5	
42	10:15	1	"	12	12	
44	10:17	[illegible]	"	15	7.5	
45	10:18	0	"	0	0	New record sheet
46	10:19	1	"	15	15	
47	10:20	1	"	11	11	
[illegible]	10:21	1	"	4	[illegible]	
[illegible]	[illegible]	1	"	7	7	[illegible]

[illegible]

[illegible] - [illegible]

No. of Observation	Time	Time Interval Min.	Temperature Degrees C	Total Distance [illegible]	Rate [illegible] per [illegible]	Remarks
51	10:28	[illegible]	[illegible].5	[illegible]	[illegible]	
[illegible]	10:30	[illegible]	"	19	9.5	
[illegible]	10:31	1	"	1[illegible]	[illegible]	
[illegible]	10:32	[illegible]	"	10	[illegible]	
[illegible]	10:33	1	"	[illegible]	1[illegible]	
[illegible]	10:34	0	"	0	0	[illegible]
57	10:35	1	"	4	[illegible]	
[illegible]	10:36	1	"	5	[illegible]	
59	10:37	1	"	5	5	
60	10:37:30	0	"	[illegible]	0	[illegible]
61	10:38	0	"	0	0	[illegible]
[illegible]	10:39	1	"	12	12	
[illegible]	10:40	1	"	1[illegible]	13	
64	10:41	1	"	13	13	
65	10:42	1	"	9	9	
66	10:42:50	1	"	5	5	
67	10:44	[illegible]	"	0	0	[illegible]
[illegible]	10:45:05	1.1	"	[illegible]	8.1	
[illegible]	10:46	0.9	"	7	7.7	
70	10:47:05	1.1	"	10	9.1	
[illegible]	10:48	[illegible]	"	10	11	
72	10:49:05	1.1	"	[illegible]	[illegible]	
73	10:50	1	"	[illegible]	3	Temp. changed, 10:50
[illegible]	10:53	0	13.5	0	0	New record sheet
75	10:54	1	"	5	5	
76	10:55	1	"	5	5	
77	10:57	[illegible]	"	4	[illegible]	
78	10:59	2	"	6	[illegible]	
79	11:01	[illegible]	"	[illegible]	[illegible]	
80	11:03	[illegible]	"	[illegible]	1	
[illegible]	11:05	[illegible]	"	5	2.5	
82	11:08	3	"	15	5	
83	11:11	3	"	[illegible]	4.3	
[illegible]	11:14	[illegible]	"	25	[illegible]	


XLVIII


XLIX

PERFORMANCE RECORD

of

[illegible]

No. of Observation	Time	Time Interval Min.	Temperature Degrees C	Total distance cm.	Rate cm. per min.	Remarks
1	[illegible]	0	20.5	0	0	
2	11:04	[illegible]	"	[illegible]	[illegible]	
3	11:05	1	"	9	9	
4	[illegible]	1	"	5	5	
5	11:07	1	"	[illegible]	3	
6	11:08	1	"	[illegible]	4	
7	11:09	1	"	[illegible]	5	
8	11:10	1	"	10	10	
9	11:11	1	"	7	7	
10	11:12	1	"	10	10	
11	11:13	1	"	7	7	
12	11:14	1	"	[illegible]	6	
13	11:15	0		-	-	Animal floating
14	11:15:[illegible]	0		-	-	" "
15	11:17	1.5	16	11	7.33	Temp., 16°, 11:16
16	11:18	1	"	[illegible]	7	
17	11:19	1	"	4	[illegible]	
18	11:20	1	"	[illegible]	4	Temp. [illegible], 11:[illegible]
19	11:22:30	0	8.5	0	0	[illegible]
20	11:24	1.5	"	3	[illegible]	Temp. [illegible], [illegible]
21	11:28	0	[illegible]	-	-	Animal floating
22	11:30	0	"	-	-	" "
23	11:31	0	"	-	-	" "
24	11:32	0	"	-	-	" "
25	11:33	0	"	-	-	" "
26	11:34	0	"	[illegible]	0	[illegible]
27	11:35	1	"	6	[illegible]	
28	11:36	1	"	5.5	5.5	
29	11:36:30	0	"	[illegible]	0	[illegible]
30	11:38	1.5	"	[illegible]	[illegible]	
31	11:39	1	"	[illegible]	[illegible]	
32	11:41	[illegible]	"	[illegible]	[illegible]	
33	11:43	[illegible]	"	[illegible]	4	
						Temp. rising slowly [illegible]
34	11:45	[illegible]	15.5	[illegible]	[illegible]	
35	11:47	0	"	-	-	
36	11:47:30	0	"	-	-	
37	11:49	1.5	"	5	3.33	
38	11:51	[illegible]	"	[illegible]	[illegible]	
39	11:53	[illegible]	"	[illegible]	[illegible]	
40	11:55	[illegible]	"	[illegible]	[illegible]	
41	11:57	[illegible]	"	[illegible]	2.5	

[illegible] - ([illegible])

No. of Observation	Time	Time Interval Min.	Temperature Degrees C	Total Millimeters Mm.	Rate Mm. per Min.	Remarks
[illegible]	11:59	[illegible]	15.5	11	[illegible]	
43	[illegible]:01	[illegible]	"	[illegible]	2.5	Observation interrupted
44	[illegible]:27	0	21	0	0	[illegible]
45	[illegible]	1	"	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible]	"	[illegible]	[illegible]	
47	[illegible]	2	"	[illegible]	1.5	

PERFORMANCE RECORD

of

[illegible] *

No. of Observation	Time	Time Interval Min.	Temperature Degrees C	Total Distance Mm.	Rate Mm. per Min.	Remarks
1	1:52	0	18	0	0	
[illegible]	1:53	1	"	[illegible]	[illegible]	
[illegible]	1:54	1	"	4.5	4.5	
[illegible]	1:56	[illegible]	"	[illegible]	4.5	
[illegible]	1:58	[illegible]	"	[illegible]	[illegible]	
[illegible]	[illegible]	2	"	9	4.5	
[illegible]	2:02	[illegible]	"	13	6.5	
[illegible]	[illegible]	2	"	[illegible]	4	
[illegible]	2:06	[illegible]	"	9	4.5	
[illegible]	2:08	2	"	[illegible]	4.5	
11	2:09	0	"	0	0	[illegible]
						[illegible]
[illegible]	2:11	[illegible]	12.5	[illegible]	3	
13	2:13	[illegible]	"	[illegible]	[illegible]	
14	2:15	[illegible]	"	4	[illegible]	
15	2:17:30	0	"	-	-	
16	2:19	0	"	0	0	[illegible]
17	2:21	2	"	2	1	
18	[illegible]	2	"	[illegible]	1.5	
19	2:25	[illegible]	"	[illegible]	1.5	
[illegible]	[illegible]	[illegible]	"	5	2.5	[illegible]
21	2:31	[illegible]	"	6	3	Temp. rose to 14.5°, 2:31:30 - 2:33:30
[illegible]	2:33	[illegible]	14.5	[illegible]	[illegible]	
[illegible]	2:34	0	12	0	0	[illegible]
[illegible]	2:36	[illegible]	"	3	0.75	
						[illegible]
						[illegible]
[illegible]	3:06	0	14	0	0	New record sheet
[illegible]	3:10	[illegible]	"	2.5	[illegible]	
29	3:13	[illegible]	"	[illegible]	1	
30	3:17	4	"	[illegible]	1.5	
31	[illegible]	3	"	[illegible]	1.7	
[illegible]	[illegible]	[illegible]	"	4.5	[illegible]	
[illegible]	[illegible]	[illegible]	"	5	[illegible]	

*Graph on same Plate with Individual [illegible].

FOLD OUT

[illegible]
of
INDIVIDUAL L

No. of Observation	Time	Time Interval Min.	Temperature Degrees C	Total Distance Mm.	Rate Mm. per Min.	Remarks
1	11:07:30	0	21	0	0	
2	11:09	1.5	"	3.5	2.33	
3	11:11	2	"	3.5	1.75	
4	11:13	2	"	3	1.5	
5	11:15	2	"	4	2	
6	11:17	2	"	4	2	Temp. changed, 11:17:30
7	11:19	2	18	8	4	
8	11:21	2	"	4.5	2.25	
9	11:23	2	"	4	2	
10	11:25	2	"	9	4.5	
11	11:27	2	"	9	4.5	
12	11:29	2	"	9	4.5	
13	11:31	2	"	6	3	
14	11:32	0	"	0	0	New record sheet
15	11:34	2	"	5	2.5	
16	11:36	2	"	7	3.5	
17	11:38	2	"	4	2	
18	11:40	2	"	3	1.5	
19	11:42	0	"	0	0	New record sheet
20	11:45	3	"	2	0.7	
21	11:47	2	"	1	0.5	
22	11:49	2	"	3	1.5	
23	11:52:30	0	"	0	0	Rest; begins to move, 11:52:30
24	11:55	2.5	"	3	1.2	
25	11:57	2	"	1.5	0.75	
26	11:59	2	"	2	1	
27	12:00:30	0	"	0	0	New record sheet
28	12:03	2.5	"	3	1.2	
29	12:05	2	"	2	1	
30	12:07	2	"	3	1.5	

PERFORMANCE RECORD
of
INDIVIDUAL II

No. of Observation	Time	Time Interval Min.	Temperature Degrees C	Total Distance Mm.	Rate Mm. per Min.	Remarks
1	12:40:30	0	19	0	0	
2	12:42	1.5	"	7	4.66	
3	12:44	2	"	5	2.5	
4	12:46	2	"	3	1.5	
5	12:48	2	"	3.5	1.75	
6	12:50	2	"	4	2	
7	12:52	2	"	11	5.5	
8	12:54	2	"	8.5	4.25	
9	12:56	2	"	8	4	
10	12:57	0	"	0	0	New record sheet
11	12:59	2	"	13	6.5	
12	1:02	3	"	6	2	
13	1:04	2	"	19	9.5	
14	1:06	2	"	15	7.5	Temp. changed, 1:07
15	1:08	2	16.5	8	4	
16	1:09	1	"	5.5	5.5	
17	1:10	1	"	4.5	4.5	
18	1:12	2	"	7.5	3.75	
19	1:14	2	"	9	4.5	
20	1:16	0	"	0	0	New record sheet
21	1:18	2	"	6	3	
22	1:20	2	"	11	5.5	
23	1:22	2	"	7	3.5	
24	1:24	2	"	5.5	2.75	
25	1:26	2	"	4	2	
26	1:29	3	"	8	2.7	
27	1:31	2	"	6	3	
28	1:33	2	"	5.5	2.75	
29	1:35	2	"	3	1:5	
30	1:37	2	"	3	1:5	
31	1:39	2	"	4	2	
32	1:41	2	"	5	2.5	
33	1:42	2	"	10	5	
34	1:44	0	"	0	0	New record sheet Temp. changed, 1:44:30
35	1:45	1	13.5	8	8	
36	1:47	2	"	4	2	
						Rest; begins to move, 1:50
37	1:52	2	"	3	1.5	
38	1:54	0	"	0	0	New record sheet
39	1:56	2	"	4.5	2.25	
40	1:58	2	"	6	3	
41	2:00:30	0	"	0	0	Animal detached from substratum
42	2:02:30	0	"	0	0	Animal detached from substratum
43	2:04	1.5	"	6	4	
44	2:06	2	"	10	5	

LI - (2)

No. of Observation	Time	Time Interval Min.	Temperature Degrees C	Total Distance Mm.	Rate Mm. per Min.	Remarks
45	2:08	2	13.5	8	4	
46	2:10	2	"	6	3	
47	2:12	2	"	9	4.5	
48	2:14	2	"	3	1.5	
49	2:15	0	"	0	0	New record sheet
50	2:17	2	"	4	2	
						Rest; begins to move, 2:19
						Temp. changed, 2:20
51	2:21	2	15.5	3	1.5	
52	2:23	2	"	8	4	
53	2:25	2	"	5	2.5	
54	2:27	2	"	7	3.5	
55	2:29	0	"	0	0	Animal detached from substratum
						Temp. changed, 2:29
56	2:34	0	14.5	0	0	
57	2:36	2	"	8	4	
58	2:38	2	"	9	4.5	
59	2:41	3	"	6.5	2.17	
						Animal detached for part of this interval
60	2:44:30	1.5	"	2.5	1.7	
61	2:46	1.5	"	2.5	1.7	Temp. changed, 2:46:30
62	2:49:30	0	10.5	-	-	No locomotion, but flow of granules
63	2:51:30	0	"	-	-	
64	2:53	0	"	-	-	
65	2:55	0	"	0	0	
66	2:57	2	"	2	1	
67	3:02	5	"	2	0.4	
68	3:05	3	"	1.5	0.5	
69	3:10:15	0	"	0	0	New starting point
70	3:12	1.75	"	2	0.9	Temp. changed, 3:12:30
71	3:16	0	12.5	0	0	New record sheet
72	3:19	3	"	2	0.7	
73	3:21	2	"	2.5	1.25	
74	3:24	3	"	2.5	0.8	
75	3:27	3	"	5	1.7	
76	3:32	5	"	5	1.1	
77	3:35	3	"	7.5	2.5	Temp. changed, 3:35:30
78	3:37:30	0	15	0	0	New record sheet
79	3:39	1.5	"	5	3.33	
80	3:42	3	"	5.5	1.83	
81	3:45	3	"	4	1.3	

*Graph on same Plate with Individual L.


III

PERFORMANCE RECORD

OF

INDIVIDUAL III

No. of Observation	Time	Time Interval Min.	Temperature Degrees C	Total Distance Mm.	Rate Mm. per Min.	Remarks
1	9:13	0	18	0	0	
2	9:14	1	"	4.5	4.5	
3	9:15	1	"	6	6	
4	9:17	2	"	6	3	
5	9:19	2	"	7	3.5	
6	9:21	2	"	11	5.5	
7	9:23	2	"	13	6.5	
8	9:23:30	0	"	0	0	New record sheet
9	9:25	1.5	"	6	4	
10	9:27	2	"	9	4.5	
11	9:29	2	"	20	10	
12	9:31	2	"	15	7.5	
13	9:33	2	"	16	8	
14	9:35	2	"	13	6.5	
15	9:37	2	"	15	7.5	
16	9:37:30	0	"	0	0	New record sheet
17	9:39	1.5	"	17	11.3	
18	9:41	2	"	23	11.5	
						Temp. changed, 9:41:30
19	9:43	2	22	18	9	
20	9:44:15	1.25	"	13	10.4	
21	9:45	.75	"	8	6	
22	9:45:30	0	"	0	0	New record sheet
23	9:47	1.5	"	14	9.3	
24	9:49	2	"	25	12.5	
25	9:51	2	"	9	4.5	
26	9:53	2	"	12	6	
27	9:54	1	"	8	8	
28	9:54:30	0	"	0	0	New record sheet
29	9:56	1.5	"	15	10	
30	9:57:30	1.5	"	7	4.66	Under debris

FOLD OUT

PERFORMANCE RECORD
of
INDIVIDUAL LIII

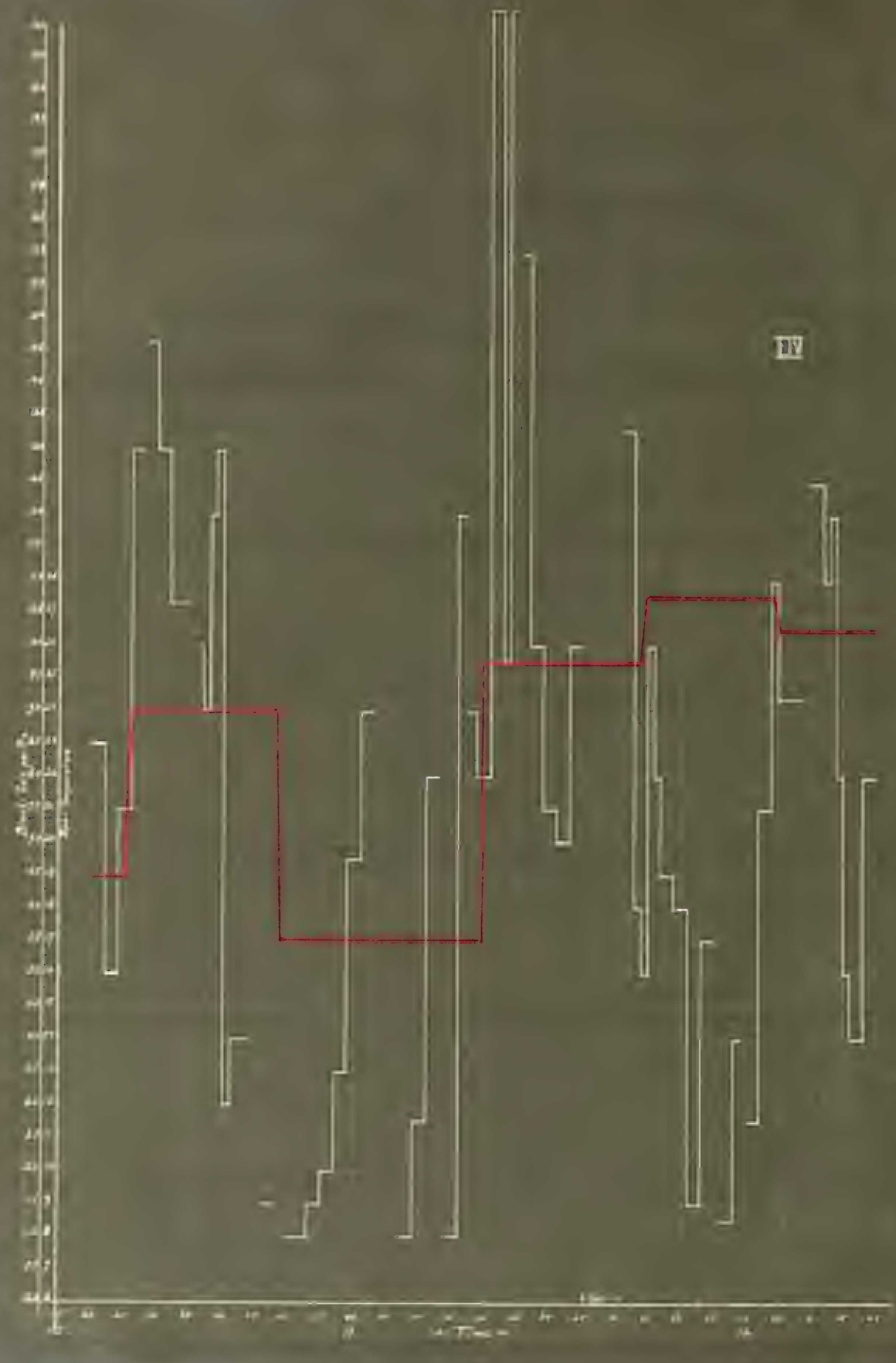
No. of Observation	Time	Time Interval Min.	Temperature Degrees C	Total Distance Mm.	Rate Mm. per Min.	Remarks
1	10:28	0	18	0	0	
2	10:30	2	"	7	3.5	
3	10:32	2	"	11	5.5	
4	10:34	2	"	15	7.5	Temp. rising
5	10:36	2	19	15	7.5	
6	10:38	2	"	14	7	
7	10:38:30	0	"	0	0	New record sheet
8	10:40	1.5	"	12	8	
9	10:42	2	"	18	9	
10	10:44	2	"	10	5	
11	10:46	2	"	17	8.5	
12	10:48	2	"	12	6	
13	10:50	2	"	20	10	
						Temp. changed, 10:51
14	10:52	2	22	20	10	
15	10:53	0	"	0	0	New record sheet
16	10:55	2	"	24	12	Reading doubtful; animal may have been floating. After observation 16 - animal detached from substratum
17	10:58	0	"	0	0	New starting point
18	11:00	2	"	25	12.5	
19	11:02	2	"	9	4.5	
20	11:04	0	"	0	0	New starting point
21	11:06	2	"	26.5	13.25	
22	11:07	0	"	0	0	New record sheet
23	11:08	1	"	3	3	
24	11:09	1	"	6	6	
25	11:11	2	"	16	8	
26	11:13	2	"	20	10	Temp. changed 11:13:30
27	11:15	2	27	14	7	
28	11:16	1	"	4	4	
29	11:17	1	"	2	2	
30	11:18	1	"	2	2	
31	11:19	1	"	2	2	
32	11:20	0	"	0	0	New record sheet
33	11:22	2	"	2	1	
34	11:24	2	"	5	2.5	
35	11:26	2	"	10	5	
36	11:27	1	"	2	2	
37	11:29	2	"	12	6	
38	11:30	1	"	11	11	
39	11:31	1	"	10	10	
40	11:33	2	"	7	3.5	
41	11:34:30	1.5	"	3	2	
						Temp. changed, 11:35

LIII - (2)

No. of Observation	Time	Time Interval Min.	Temperature Degrees C	Total Distance Mm.	Rate Mm. per Min.	Remarks
42	11:36	1.5	25.5	3	2	
43	11:37	1	"	3	3	
44	11:38	0	"	0	0	New record sheet
45	11:40	2	"	3	1.5	
46	11:42	2	"	11	5.5	
47	11:44	2	"	12	6	
48	11:45	1	"	4	4	
49	11:46	0	"	0	0	New record sheet
50	11:48	2	"	9.5	4.75	
51	11:50	2	"	16	8	
52	11:51	1	"	3	3	
53	11:53	2	"	8	4	
54	11:55	2	"	10	5	
55	11:57	2	"	4	2	
56	11:58	0	"	0	0	New record sheet
						Temp. changed, 11:58:30
57	12:00	2	24	5	2.5	
58	12:02	2	"	4	2	
59	12:04	2	"	10	5	
60	12:06	2	"	3	1.5	
61	12:09	3	"	8	2.66	
62	12:11	2	"	12	6	
63	12:13	2	"	11	5.5	
64	12:15	2	"	10	5	
65	12:17	2	"	11	5.5	
66	12:18	0	"	0	0	New record sheet
67	12:20	2	"	3.5	1.75	
68	12:22	2	"	5	2.5	
69	12:24	2	17	9	4.5	Between observation 69-72, temp.unsteady
70	12:26	2	"	2	1	
71	12:28	2	"	1	0.5	
72	12:30	2	"	2.5	1.25	
						Rest; begins movement, 12:50
73	12:50	0	"	0	0	New record sheet
74	12:51	1	"	2	2	
75	12:53	2	"	2	1	
76	12:55	2	"	6	3	
77	12:57	2	"	9	4.5	
78	12:59	2	"	10	5	
79	1:01	2	"	8	4	
80	1:01:30	0	"	0	0	New record sheet
81	1:03	1.5	"	2	1.33	
82	1:04	1	"	13	13	
83	1:06	2	"	17	8.5	
84	1:08	2	"	13	6.5	
85	1:10	2	"	16	8	
86	1:12	0	"	0	0	New record sheet
87	1:15	3	"	35	11.66	

LIII - (3)

No. of Observation	Time	Time Interval Min.	Temperature Degrees C	Total Distance Mm.	Rate Mm. per Min.	Remarks
88	1:17	2	17	16	8	
89	1:18	1	"	8	8	
90	1:19	1	"	5	5	
91	1:20	1	"	8	8	
92	1:21	0	"	0	0	New record sheet Temp. changed, 1:21:30
93	1:23	2	25	27	13.5	
94	1:27	4	"	17	4.25	
95	1:30	3	"	10	3.33	

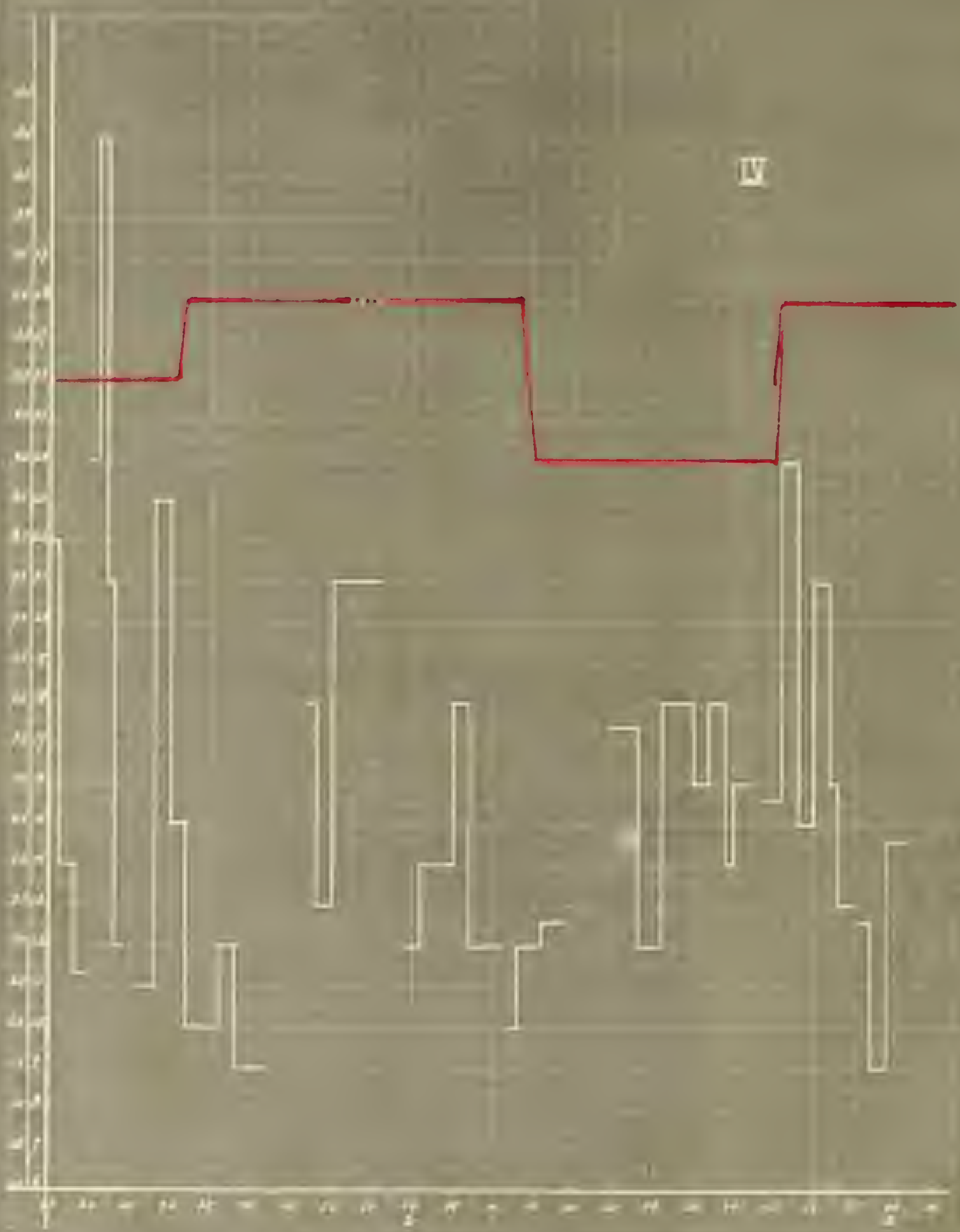

IV

PERFORMANCE RECORD
of
INDIVIDUAL LIV

No. of Observation	Time	Time Interval Min.	Temperature Degrees C	Total Distance Mm.	Rate Mm. per Min.	Remarks
1	10:20	0	19	0	0	
2	10:22	2	"	17	8.5	
3	10:24	2	"	10	5	
						Temp. changed, 10:25
4	10:26	2	24	15	7.5	
5	10:28	2	"	26	13	
6	10:28:30	0	"	0	0	New record sheet
7	10:30	1.5	"	22	14.66	
8	10:32	2	"	26	13	
9	10:35	3	"	32	10.66	
10	10:36	0	"	0	0	New record sheet
11	10:37	1	"	10	10	
12	10:38	1	"	9	9	
13	10:39	1	"	12	12	
14	10:40	1	"	13	13	
15	10:41	1	"	3	3	
16	10:43	2	"	8	4	
17	10:44	1	"	4	4	
18	10:46	0	"	0	0	New record sheet
19	10:48	2	"	3	1.5	Temp. changed, 10:48:30
20	10:50	0	17	0	0	New starting point
21	10:53	3	"	3	1	
22	10:55	2	"	3	1.5	
23	10:57	2	"	4	2	
24	10:59	2	"	7	3.5	
25	11:01	2	"	13.5	6.75	
26	11:03	2	"	18	9	
27	11:03:30	0	"	0	0	New record sheet
28	-----	0	"	-	-	In same place, 11:05
29	11:07	2	"	2	1	
30	11:09	2	"	2	1	
31	11:11	2	"	5.5	2.75	
32	11:13	2	"	16	8	
33	11:14	0	"	0	0	New record sheet
34	11:16	2	"	2	1	
35	11:17	1	"	12	12	
36	11:17:30	0	"	0	0	New starting point
37	11:19	1.5	"	13	9	Temp. changed, 11:19:30
38	11:21	2	25.5	16	8	
39	11:23	2	"	40	20	
40	11:24	1	"	10	10	
41	11:25	1	"	20	20	
42	11:26	0	"	0	0	New record sheet
43	11:27	1	"	16	16	
44	11:29	2	"	20	10	
45	11:31	2	"	15	7.5	
46	11:33	2	"	14	7	
47	11:35	2	"	20	10	Rest

IIV - (2)

No. of Observation	Time	Time Interval Min.	Temperature Degrees C	Total Distance Mm.	Rate Mm. per Min.	Remarks
48	11:41:30	0	25.5	0	0	New record sheet
49	11:43	1.5	"	20	13.33	
50	11:44	1	"	6	6	
						Temp. changed, 11:44:15
51	11:45	1	27.5	5	5	
52	11:46	1	"	10	10	
53	11:47	1	"	8	8	
54	11:49	2	"	13	6.5	
55	11:51	2	"	12	6	
56	11:53	2	"	3	1.5	
57	11:55	2	"	11	5.5	
58	11:56	0	"	0	0	New record sheet
59	11:58	2	"	2.5	1.25	
60	11:59	1	"	4	4	
						In same place, 12:00
61	12:02	2	"	5	2.5	
62	12:04	2	"	15	7.5	Temp. changed, 12:04:30
63	12:05	1	26.5	11	11	
64	12:09	4	"	37	9.2	
65	12:10	0	"	0	0	New record sheet
66	12:12	2	"	25	12.5	
67	12:13	1	"	11	11	
68	12:14	1	"	12	12	
69	12:15	1	"	8	8	
70	12:16	1	"	5	5	
71	12:17	1	"	4	4	
72	12:18	1	"	4	4	
73	12:20	2	"	16	8	
74	12:22	2	"	16	8	


IV

PERFORMANCE RECORD
of
INDIVIDUAL LV

No. of Observation	Time	Time Interval Min.	Temperature Degrees C	Total Distance Mm.	Rate Mm. per Min.	Remarks
1	1:15	0	26	0	0	
2	1:16	1	"	8	8	
3	1:18	2	"	8	4	
4	1:19:30	1.5	"	4	2.[illegible]	
5	1:20	0	"	0	0	New record sheet
6	1:21	1	"	9	9	
7	1:22	1	"	13	13	
8	1:23	1	"	7.5	7.5	
9	1:24	1	"	3	3	
10	1:26	0	"	0	0	New record sheet
11	1:28	2	"	5	2.5	
12	1:30	2	"	17	8.5	Temp. changed, 1:31
13	1:32	2	28	9	4.5	
14	1:34	2	"	4	2	
15	1:36	2	"	4	2	
16	1:38	2	"	6	3	
17	1:40	2	"	3	1.5	
18	1:42	2	"	3	1.5	
19	1:42:30	0	"	0	0	New record sheet Rest; begins to move, 1:46:30
20	1:48	1.5	"	9	6	
21	1:50	2	"	7	3.5	
22	1:52	2	"	15	7.5	Temp. varied for 3.5° after 1:52:30
23	1:54	2	"	15	7.5	
24	1:56	2	"	15	7.5	Rest; begins to move, 1:59
25	1:59	0	"	0	0	New record sheet
26	2:01	2	"	6	3	
27	2:03	2	"	8	4	
28	2:05	2	"	8	4	
29	2:07	2	"	12	6	
30	2:09	2	"	6	3	
31	2:11	2	"	6	3	
32	2:12	0	"	0	0	New record sheet
33	2:13	1	"	2	2	Temp. changed, 2:12:30
34	2:16	3	24	9	3	
35	2:19	3	"	10	3.33	
36	2:24:30	0	"	0	0	Animal under debris
37	2:28	3.5	"	20	5.7	
38	2:31	3	"	9	3	
39	2:33	2	"	12	6	
40	2:35	2	"	12	6	
41	2:37	2	"	10	5	
42	2:39	2	"	12	6	
43	2:40	1	"	4	4	
44	2:42	2	"	10	5	

LV - (2)

No. of Observation	Time	Time Interval Min.	Temperature Degrees C	Total Distance Mm.	Rate Mm. per Min.	Remarks
45	2:43:30	0	24	0	0	New record sheet Temp. changed, 2:45
46	2:46	2.5	38	12	4.8	
47	2:48	2	"	18	9	
48	2:50	2	"	9	4.5	
49	2:52	2	"	15	7.5	
50	2:53	1	"	5	5	
51	2:55	2	"	7	3.5	
52	2:55:30	0	"	0	0	New record sheet
53	2:57	1.5	"	5	3.33	
54	2:59	2	"	3	1.5	
55	3:02	3	"	13	4.3	

FOLD OUT

[illegible]

of

[illegible]

No. of Observation	Time	Time Interval Min.	Temperature Degrees C	Total [illegible]	Rate [illegible] per Min.	Remarks
1	1:40	0	[illegible]	[illegible]	0	
2	1:41	1	"	[illegible]	[illegible]	
3	[illegible]	[illegible]	"	[illegible]	7	
4	1:45	[illegible]	"	[illegible]	[illegible]	
5	1:46:30	1.5	"	[illegible]	10	
6	1:47	0	"	[illegible]	[illegible]	[illegible]
7	1:49	2	"	15	[illegible]	
8	1:51	2	"	12	[illegible]	
9	1:53	2	"	[illegible]	[illegible]	
10	1:55	2	"	15	7.5	
11	1:55:30	0	"	[illegible]	0	[illegible]
12	1:58	2.5	"	19	7.6	
13	2:00	2	"	13.5	6.7	
14	2:02	2	"	15	7.5	
15	2:04	2	"	15	7.5	
16	[illegible]	0	"	0	0	[illegible]
17	[illegible]	1.5	"	12.5	8.33	
18	2:08	2	"	12.5	6.25	
19	2:10	2	"	16	[illegible]	[illegible]
20	2:12	[illegible]	16.5	19	[illegible]	
21	[illegible]	2	"	13	6.5	
22	2:16	2	"	7	3.5	
23	2:18	2	"	11	5.5	
24	[illegible]	1.5	"	[illegible]	[illegible]	
25	[illegible]	0	"	0	0	[illegible]
26	[illegible]	1.8	"	13	[illegible]	
27	2:24	2	"	15	7.5	
28	[illegible]	2	"	12	[illegible]	
29	2:28	2	"	11	5.5	
30	2:30	2	"	17	8.5	
31	[illegible]	0	"	[illegible]	[illegible]	[illegible]
32	2:32	1.5	"	9	[illegible]	
33	[illegible]	2	"	15	7.5	
34	2:36	2	"	15	7.5	
35	2:38	2	"	16	[illegible]	
36	[illegible]	1.5	"	14	9.33	[illegible]
37	[illegible]	2.5	[illegible]	7	[illegible]	[illegible]
38	2:44	2	"	11	5.5	
39	[illegible]	0	"	[illegible]	0	[illegible]
40	[illegible]	[illegible]	"	6.5	[illegible]	
41	2:50	[illegible]	"	[illegible]	[illegible]	[illegible]
42	2:52	[illegible]	"	[illegible]	[illegible]	
43	2:54	[illegible]	"	[illegible]	[illegible]	
44	2:56	2	"	11	5.5	
45	2:57	1	"	[illegible]	[illegible]	

[illegible]

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	0	[illegible]	[illegible]	[illegible]	New record sheet
[illegible]	[illegible]	[illegible]	"	[illegible]	[illegible]	
[illegible]	3:02	[illegible]	"	7	[illegible]	
						[illegible]
[illegible]	3:07	[illegible]	"	11	[illegible]	
50	[illegible]	[illegible]	"	[illegible]	[illegible]	[illegible]
51	3:12	0	"	0	[illegible]	[illegible]
52	3:14	0	"	0	[illegible]	" "
53	3:16	[illegible]	"	15	[illegible]	
54	3:18	[illegible]	"	[illegible]	[illegible]	
55	3:19	[illegible]	"	0	[illegible]	[illegible]
56	3:21	[illegible]	"	11	[illegible]	
57	[illegible]	[illegible]	"	20	[illegible]	[illegible]
[illegible]	3:25	[illegible]	[illegible]	20	10	
59	3:26	[illegible]	"	0	[illegible]	[illegible]
60	3:28	[illegible]	"	—	—	[illegible]
61	3:31	3	[illegible]	16	5.33	
62	3:34	[illegible]	"	23	7.7	
63	3:36	2	"	10	[illegible]	
[illegible]	3:38	2	"	[illegible]	[illegible]	
65	3:40	[illegible]	"	[illegible]	[illegible]	
66	3:42	[illegible]	23	[illegible]	2.5	
67	3:45	3	"	10	3.33	
68	3:46	0	"	0	[illegible]	[illegible]
69	[illegible]	[illegible]	"	[illegible]	[illegible]	
[illegible]	3:50	[illegible]	"	[illegible]	[illegible]	[illegible]
[illegible]	3:52	[illegible]	21	[illegible]	2.5	
[illegible]	[illegible]	2	"	7	3.5	
73	3:57	[illegible]	"	[illegible]	5.33	
[illegible]	3:59	[illegible]	"	[illegible]	7.5	
75	4:01	[illegible]	"	4	2	
[illegible]	4:02	[illegible]	"	0	[illegible]	[illegible]
77	4:04	[illegible]	"	[illegible]	[illegible]	
[illegible]	4:06	[illegible]	"	[illegible]	[illegible]	
[illegible]	4:08	2	"	10	[illegible]	
[illegible]	[illegible]	2	"	[illegible]	[illegible]	
81	4:12	[illegible]	"	[illegible]	[illegible]	[illegible]
[illegible]	4:14	[illegible]	[illegible]	[illegible]	[illegible]	
83	4:16	[illegible]	[illegible]	[illegible]	1.5	


XVII


XVIII

[illegible]

[illegible]

No. of Observation	Time	Time interval Min.	Temperature Degrees F	Total Distance Mm.	Rate mm. per Min.	Remarks
1	[illegible]	0	19.5	[illegible]	[illegible]	
[illegible]	10:44	[illegible]	"	[illegible]	[illegible]	
[illegible]	10:46	[illegible]	"	11	[illegible]	
[illegible]	10:48	[illegible]	"	[illegible]	[illegible]	[illegible]
5	10:50	[illegible]	"	[illegible]	[illegible]	
[illegible]	10:52	[illegible]	"	[illegible]	[illegible]	
7	[illegible]	2	"	[illegible]	[illegible]	
8	[illegible]	[illegible]	"	[illegible]	4.5	
[illegible]	10:58	[illegible]	"	11.5	[illegible]	
[illegible]	11:00	2	"	14.5	7.25	
11	11:00:30	0	"	[illegible]	0	[illegible]
[illegible]	11:02	1.5	"	[illegible]	[illegible]	
13	11:04	[illegible]	"	[illegible]	[illegible]	[illegible]
[illegible]	11:06	[illegible]	"	[illegible]	[illegible]	
15	11:08	4	"	7	1.8	
16	11:10		"			
17	11:12	[illegible]	"	[illegible]	6.5	
18	11:14	2	"	[illegible]	[illegible]	
						[illegible]
19	11:16	[illegible]	[illegible]	[illegible]	[illegible]	
[illegible]	11:18	[illegible]	"	[illegible]	[illegible]	
[illegible]	11:20	2	"	4	[illegible]	
22	11:22	[illegible]	"	[illegible]	[illegible]	
23	11:22:30	0	"	0	[illegible]	[illegible]
24	11:24	1.5	"	[illegible]	4	
25	11:26	2	"	[illegible]	[illegible]	
26	11:28	[illegible]	"	[illegible]	[illegible]	
						[illegible]
27	11:32	2	"	[illegible]	3.5	
28	11:34	2	"	[illegible]	2.5	
29	11:36	2	"	[illegible]	1.5	
30	11:38	2	"	3.5	1.75	
31	11:40	[illegible]	"	3	[illegible]	
						[illegible]
32	11:42	[illegible]	[illegible]	2	1	
[illegible]	11:44	[illegible]	"	2	1	
[illegible]	11:46	2	"	[illegible]	[illegible]	
35	11:48	[illegible]	"	[illegible]	[illegible]	
[illegible]	11:50	[illegible]	"	[illegible]	[illegible]	
37	11:52	[illegible]	"	6.5	[illegible]	
38	11:54	[illegible]	"	[illegible]	[illegible]	
						[illegible]

[illegible]

[illegible]

[illegible] *

No. of Observation	Time	Time Interval Min.	Temperature Degrees C	Total Movements No.	Rate No. per Min.	Remarks
1	11:16	[illegible]	[illegible]	[illegible]	[illegible]	
2	11:18	2	"	[illegible]	[illegible]	
3	11:20	2	"	[illegible]	[illegible]	
4	11:22	2	"	13	[illegible]	
5	[illegible]	2	"	[illegible]	[illegible]	
6	11:25:30	[illegible]	"	[illegible]	[illegible]	[illegible]
						[illegible]
7	[illegible]	2	"	[illegible]	[illegible]	
8	[illegible]	[illegible]	"	11	[illegible]	
9	11:32:30	[illegible]	"	10	7	
10	11:33	[illegible]	"	[illegible]	[illegible]	[illegible]
11	11:35	[illegible]	"	11	5.5	
12	11:37	[illegible]	"	[illegible]	[illegible]	
13	11:39	[illegible]	"	[illegible]	[illegible]	
14	11:41	[illegible]	"	13	6.5	
15	11:43	2	"	11	5.5	
16	11:45	[illegible]	"	[illegible]	[illegible]	
17	[illegible]	[illegible]	"	[illegible]	[illegible]	
18	11:49	[illegible]	"	15	7.5	
19	11:51	[illegible]	"	[illegible]	[illegible]	
20	11:53	[illegible]	"	7	[illegible]	
						[illegible] place but [illegible] to move
21	11:57	[illegible]	"	[illegible]	[illegible]	
[illegible]	11:59	[illegible]	"	[illegible]	[illegible]	

*[illegible]

PERFORMANCE RECORD
of
INDIVIDUAL [illegible]

No. of Observation	Time	Time Interval Min.	Temperature Degrees C	Total Distance Mm.	Rate Mm. per Min.	Remarks
1	1:48	0	20	0	0	
2	1:50	2	"	9	4.5	
3	1:52	2	"	8	4	Animal feeding
4	1:55:30	0	"	0	0	New starting point
5	1:57	1.5	"	10	7	
6	1:59	2	"	10.5	5.25	
						Temp.changed, 1:59:30
7	2:01	2	21.5	7	3.5	
8	2:03	2	"	10	5	
9	2:05	2	"	9	4.5	
10	2:07:30	0	"	0	0	New record sheet
11	2:09	2	"	5	2.5	Crawling under debris
12	2:14:30	0	"	0	0	
13	2:17	2.5	"	5	1	
14	3:03	0	"	0	0	New starting point
15	3:05	2	"	13	6.5	
16	3:07	2	"	10	5	
17	3:09	2	"	25.5	12.75	
18	3:09:30	0	"	0	0	New record sheet
19	3:11	1.5	"	12	8	
20	3:13	2	"	12	6	
21	3:15	2	"	16	8	
22	3:17	2	"	8	4	

For biography of author see page 1[illegible].